



New England

Vegetable Management Guide

2020-2021 Edition



**Vegetable Crop Production
from Seed to Harvest**



Cover photo credit:
Farmers and Extension Educators scout onions at High Meadows Farm in Westminster, VT.
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2020-2021 New England Vegetable Management Guide

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About the Guide

This guide is intended to assist commercial vegetable producers by providing information on production techniques and pest management. Sustaining New England's vegetable farms will require that farmers make profits as well as sound management decisions that protect the environment and promote social acceptance of agriculture. We in the Cooperative Extension system are committed to providing farmers with the information necessary to make the best possible management choices.

Although this guide lists nearly all pesticides labeled for use on vegetable crops, growers should utilize an integrated management approach that considers cultural practices and biological interactions whenever possible. To support vegetable growers in this approach, this guide includes information on many cultural practices and non-pesticide Integrated Pest Management methods that provide the foundation for healthy crops. In addition, a comprehensive section on cover crops, soil fertility, and nutrient management is included. Information is

provided for diverse management systems, including large and small farms, and both conventional and organic production.

Cooperative Extension and other organizations publish a variety of fact sheets, manuals, and books to assist in properly managing soils and pests (see the Reference section in Appendices, at the end of the Guide). IPM programs are available in some states to help growers learn about scouting for pests and timing controls to get the best results. Finally, this guide is just one part of Extension's efforts to help support you, the vegetable grower. We also offer many educational meetings and conferences to provide you with information. We urge you to take part in these programs and to call upon us for assistance.

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The New England Vegetable Management Guide is a collaborative effort of Cooperative Extension vegetable programs in the six New England states:

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Warning! Agrichemicals/Pesticides are dangerous. Read and follow all instructions and safety precautions on labels. Carefully handle and store agrichemicals/pesticides in originally labeled containers out of the reach of children, pets and livestock. Dispose of empty containers immediately in a safe manner and place. Contact your State Department of Environmental Protection or similar agency for current regulations.

The user of this information assumes all risks for personal injury or property damage.

Ordering and Downloads

To purchase copies of the 2020-2021 New England Vegetable Management Guide and/or Pest ID Guide, contact your state Extension publication office, or the University of Massachusetts Extension Bookstore. Orders can be placed online at www.umassextensionbookstore.com or by phone by contacting the Extension Bookstore at (413) 545-5227. Payment can be made by credit card over our secure portal or you may mail in payment by check after placing your order.

Online access to the Northeast Vegetable and Strawberry Pest Identification Guide- You may view or download the Pest ID Guide in pdf format.

The 2020-2021 New England Vegetable Management Guide was produced at the University of Massachusetts Extension Vegetable Program. UMass Extension provides equal opportunities in programs and employment.

2020-2021 New England Vegetable Management Guide

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Abbreviations

Abbrev.	Description	Abbrev.	Description	Abbrev.	Description
ai	active ingredient	lb	pound	pt	pint
/A	per acre	L/LC	liquid concentrate	qt	quart
AS/AF	aqueous suspension, aqueous flowable	OG	Indicates a pesticide that has been listed by the Organic Materials Review Institute (OMRI) as compliant with the National Organic Standards and therefore approved for use in organic production.	REI	restricted entry interval
bu	bushel	OMRI	Organic Materials Review Institute, an organization that reviews products for compliance with the National Organic Standards. See www.omri.org .	S/SC	soluble concentrate, spray concentrate
D	dust	oz	ounce	SL	slurry
DF	dry flowable	PHI	pre-harvest interval	SP	soluble powder
E/EC	emulsifiable concentrate (emulsible/emulsion/miscible)	p.s.i.	pounds per square inch	sq	square (foot or yard)
F/FL	flowable formulation			tbsp	tablespoon (level)
FM	flowable microencapsulated			tsp	teaspoon (level)
fl oz	fluid ounce			WDG	water Dispersable Granules
G	granular			WG	wettable Granules
gal	gallon			W/WP	wettable powder
h	hour			W/SL	water-soluble liquid
hyb	hybrid			WSP	wettable, soluble powder
				*	federally-restricted pesticide

Throughout this publication, trade names (i.e., company names) begin with a capital letter and common names begin with a lower case letter.

Cultural Practices

CROP BUDGETS

Budgets are simply a formal means of organizing relevant economic information to help you make business decisions. Enterprise budgets that list receipts, costs, and net returns for a single product are a fundamental planning and analysis tool.

The receipts, costs and net returns on an enterprise budget are commonly shown for a year, coinciding with the business reporting cycle. Enterprise budgets are especially helpful for evaluating the feasibility of an existing or potential crop, and for developing a crop's target market price. Additionally, vegetable enterprise budgets expressed on a per acre basis allow for comparisons across crops, between farms, and over several years.

Many websites offer a good starting point when developing crop enterprise budgets. Sites listing specific vegetable enterprise budgets include:

AgMRC Vegetable Budgets

<http://www.agmrc.org/commodities-products/vegetables/>

Cornell High Tunnel Budgets

<http://blogs.cornell.edu/hightunnels/economics/>

UK Center for Crop Diversification 2013 Vegetable and Melon Budgets

<http://www.uky.edu/Ag/CDBREC/vegbudgets13.html>

Wisconsin 2014 Fresh Market Vegetable Budgets

<https://fyi.extension.wisc.edu/farmteam/enterprise-budgets/>

In addition to the above sites, the National Agricultural Risk & Farm Management Library has a budget library easily searched by commodity and geographic area. See <https://agrisk.umn.edu/Budgets>.

As a final note, when reviewing enterprise budgets developed elsewhere, it is important to identify the author's assumptions about the methods of production, levels of input use and market channels. These assumptions have a significant influence on receipt and cost estimates. Enterprise budgets taken off the web should be modified and the numbers adjusted to fit your specific resources, practices and markets.

For assistance with enterprise budget development and evaluation, contact your local Cooperative Extension office and/or USDA Service Center.

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PLANT NUTRIENTS

This section briefly describes the major and minor nutrients required by all crop plants. The following section, Fundamentals

of Soil Health and Soil Fertility Management, addresses the responsible application of fertilizers and soil amendments and stewardship of soils to economically and efficiently provide plant nutrients while minimizing losses and subsequent negative environmental effects. The third and fourth sections, Soil Testing and Fertilizers and Soil Amendments, describe soil testing methods and the many inputs commonly used to provide crop nutrient needs.

An element is considered essential to plant growth if it becomes part of plant tissue or is involved in metabolic functions and the plant cannot complete its lifecycle without it. There are 17 elements currently considered essential to plant growth. Listed in order of abundance in plant tissue, the 17 essential elements are: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Sulfur (S), Chlorine (Cl), Iron (Fe), Boron (B), Manganese (Mn), Zinc (Zn), Copper (Cu), Molybdenum (Mo), and Nickel (Ni). Plants obtain C, H, and O from air and water during photosynthesis. Together, these three elements make up approximately 95% of a plant's dry matter. Plants obtain the other 14 essential elements, called mineral nutrients, from soil. The mineral nutrients are classified as either macronutrients or micronutrients based on their relative abundance in plants. The six macronutrients, required in relatively large quantities, are N, P, K, S, Ca, and Mg. The eight micronutrients, required in relatively small quantities, are Cl, Fe, B, Mn, Zn, Cu, Ni, and Mo. Other nutrients, such as Silicon (Si), have shown to be beneficial in crop growth and disease suppression, but are not essential for the plant to complete its life cycle.

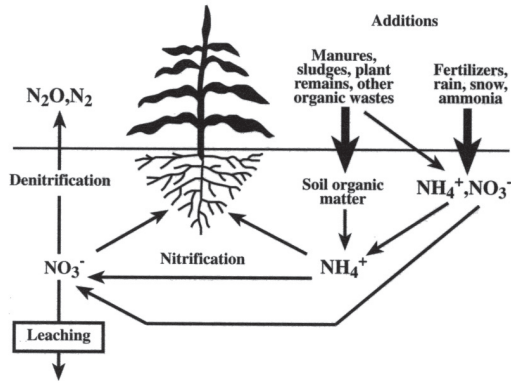
Nitrogen

Nitrogen is essential to nearly every aspect of plant growth, but it is one of the most difficult nutrients to manage. When plant available N exceeds crop demand, nitrate (NO₃) accumulates in soil, increasing the risk of N loss to the environment. Excessive levels of available N can also produce succulent plants that are more susceptible to environmental stress and pest pressure. When plant-available N is too low, crop health and productivity suffer. Understanding the forms of N in the soil and the factors that influence them will help improve management of this dynamic nutrient.

The Nitrogen Cycle

Practical knowledge of the N cycle is key to effective and efficient N management. The N cycle is extremely dynamic and its behavior in soil is complex. Nitrogen transformations and losses are affected by the form of N added, soil characteristics and conditions, and the vagaries of the weather. The rate and magnitude of N transformations and losses are difficult to accurately predict.

Figure 1. The Nitrogen Cycle



Nitrogen Inputs

As shown in Figure 1, there are two forms of the N used by plants: ammonium (NH_4) and nitrate (NO_3). In addition to commercial fertilizer sources, plant-available N in the soil may increase through mineralization (the microbial conversion of organic N to ammonium and then nitrate) of soil organic matter, manure and other organic residuals. See also Fertilizers and Soil Amendments, page 13.

Nitrogen in soil organic matter: Organic matter contains the largest pool of soil N, usually comprising more than 90% of total soil N. The total amount of organic matter N in the plow layer of agricultural soils is impressively large. As a rule of thumb, you can assume that for each 1% of organic matter in the surface 6 inches of soil, there are 1000 lbs of N per acre. Thus, a soil with 3% organic matter contains about 3000 lbs of N per acre.

The amount of total organic matter N that becomes available to plants in any one year, is relatively small as a percentage of the total organic matter. For most soils, 2%-4% of the total organic matter N is mineralized, or converted to forms plants can use, annually. This is roughly equivalent to 20-40 lb of available N per acre for each 1% of organic matter in the surface 6 inches of soil. This mineralization is not constant throughout the growing season, however. A flush of available N is normally mineralized in late spring with lower rates of mineralization occurring during the growing season. Moisture conditions will greatly influence mineralization, with the highest rates when the soil is well-aerated and near water holding capacity. Small flushes of N will be released when dry soils are re-wetted during the season. The rate of mineralization is dependent on the activity of microbes, especially bacteria. Such activity is favored by warm, well aerated soils with adequate, but not excessive moisture and a pH above 6.0. These conditions are also favorable for the growth of most vegetables. Excessively wet conditions can greatly limit bacterial activity, and therefore N mineralization. For these reasons, the N contribution of mineralizing soil organic matter is frequently estimated at a conservative rate of 10 lb of available N per acre for each 1% of organic matter in the top 6 inches of soil.

Nitrogen found in manures and other waste products is discussed extensively in Fertilizers and Soil Amendments.

Previous crops: Many vegetables leave little residue in the field and thus they provide little N benefit to subsequent crops. However, previous forage or cover crops can supply

large amounts of N to succeeding crops. Legumes, such as alfalfa and red clover, can furnish 100 lb or more of N to crops that follow (Table 1). Other legumes, mixed grass-legume stands and grass sods supply less N to succeeding crops. Keep in mind that most of the N is in the leaves, not the roots. If a legume hay crop is harvested, most of the N is removed from the field along with the hay.

Table 1: Nitrogen Credits from Previous Crops

Previous Crop	Nitrogen Credit lb N per acre
"Fair" clover (20%-60% stand)	40-60
"Good" clover (60%-100% stand)	60-90
"Fair" alfalfa (20%-60% stand)	60-90
"Good" alfalfa (60%-100% stand)	100-150
"Good" hairy vetch winter cover crop	120-150
Grass sod	20-40
Sweet corn stalks	30

Nitrogen Losses

Nitrogen losses occur in several ways. The loss of available soil N not only costs growers money, it has the potential to negatively impact both air and water quality. Understanding the cause of N losses can help growers make management decisions to improve N use efficiency and minimize negative environmental impact.

Volatilization Losses: These losses occur mainly from surface applied manures and urea. The losses can be substantial; more than 30% of the N in topdressed urea can be volatilized if there is no rain or incorporation within two or three days of application. Losses are greatest on warm, breezy days. Volatilization losses tend to be greater from sandy soils and when pH values are above 7.0. Delaying the incorporation of manures after they are spread also leads to volatilization losses of N. Under the right conditions more than 50% of the ammonium N may be volatilized within the first 48 hours following surface application of manure without incorporation.

Not only does volatilization reduce the fertilizer value of manure and urea, it can degrade air and water quality. Ammonia in the atmosphere can form particulates that contribute to smog. Ammonia emissions can also contribute to eutrophication of surface waters via atmospheric deposition.

Leaching Losses: The nitrate form of N is especially mobile in soil and is prone to leaching losses. Leaching losses are greatest on permeable, well-drained to excessively-drained soils underlain by sands or sand and gravel when water percolates through the soil. Percolation rates are generally highest when the soil surface is not frozen and evapotranspiration rates are low. Thus, October, November, early December, late March and April are times when percolation rates are highest and leaching potential is greatest. This is why nitrate remaining in the soil after the harvest of annual crops such as corn in September is particularly susceptible to leaching. The use of fall cover crops can take up this residual N and prevent it from leaching. The N will then be released for crop use after the cover crop is plowed down in the spring. Of course, leaching can occur any time there is sufficient rainfall or irrigation to saturate the soil. This is why it is important to attempt to match fertilizer N application rates with crop N needs.

Nitrate leaching accounts for the vast majority of N losses from cropland. Nitrate leaching can have a direct impact on water quality. When nitrate leaching contaminates groundwater serving drinking water supplies, human health can be impacted. The greatest concern is for infants; high levels of nitrate can be toxic to newborns, causing anoxia, also known as “blue-baby” syndrome. High nitrate levels in drinking water are also harmful to young or pregnant livestock. Depending on regional hydrology, leaching losses of nitrate can also contaminate surface waters.

Denitrification Losses: These losses occur when nitrate is converted to gases such as nitrous oxide (N_2O) and nitrogen (N_2). The conversions occur when the soil becomes saturated with water. Poorly drained soils are particularly susceptible to such losses. In especially wet years on some soils, more than half the fertilizer N applied can be lost through denitrification. The most favorable conditions for denitrification occur in early spring and late fall. Minimizing the concentration of nitrate in the soil during these periods by delaying N application in the spring and planting cover crops in the fall will help reduce denitrification losses.

Most of the N lost during denitrification is in the form of the inert nitrogen gas (N_2) which has no negative impact on the environment (our atmosphere is approximately 78% N_2). Only a small percentage of denitrified N is lost as nitrous oxide (N_2O); however, it is a powerful greenhouse gas. The impact of 1 lb of nitrous oxide on atmospheric warming is over 300 times greater than 1 lb of carbon dioxide. Agricultural activities account for over 70% of nitrous oxide emissions in the US.

Immobilization: Immobilization occurs when soil microorganisms absorb plant-available forms of N. The N is not really lost from the soil because it is held in the bodies of the microorganisms. Eventually, this N will be converted back to plant-available forms. In the meantime, however, plants are deprived of this N, and N shortages in the plants may develop. Immobilization takes place when highly carbonaceous materials such as straw, sawdust or woodchips are incorporated into the soil. Manure with large amounts of bedding and compost with C:N ratios greater than 30:1 may cause some immobilization.

Crop Removal of Nitrogen: A significant quantity of N is removed from soil via crop harvest. For example, good sweet corn crops may remove over 150 lb N per acre annually. Anticipated crop removal of N is one of the factors used in making N fertilizer recommendations. Depending on the crop, variable amounts of the nitrogen taken up by the crop are returned to the soil after harvest in nonharvested plant parts. With sweet corn this can be as much as 100 lb N per acre. As these leaves and stalks decompose, the N is released into the soil for use by a subsequent crop. Cover crops can take up much of this N to prevent losses by leaching or denitrification.

Nitrogen Management

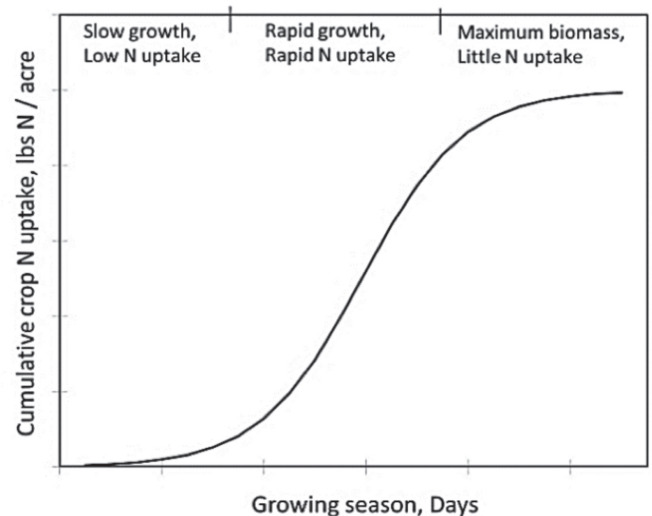
Topdressing and Sidedressing Nitrogen

Topdressing is defined as a fertilizer application to a crop any time after planting. In popular usage, topdressing sometimes refers to a broadcast application of fertilizer made after planting. However, the fertilizer can be sidedressed as a

band along the side of the row of a growing crop. Sidedressing is commonly done immediately before or during cultivation. When urea containing fertilizers are used, cultivation helps reduce volatilization losses.

Sidedressing of relatively soluble N fertilizer is an important component of efficient nitrogen management. The N accumulation pattern for annual crops is very similar to biomass accumulation (Figure 2). Early in the season, when crop growth is slow, crop N needs are very small. A starter fertilizer is generally sufficient to satisfy those needs. Any soil nitrate in excess of crop N needs during this period is prone to leaching and/or denitrification losses. The next phase of crop development is characterized by rapid vegetative growth. The N demand during this phase is the highest of the growing season. As much as 85% of the total N uptake occurs during this period. Efficient recovery of the fertilizer portion of N can be achieved by sidedressing fertilizer N immediately before this phase. Delaying application of a large portion of N fertilizer until sidedress also allows growers to use the Pre-sidedress Soil Nitrate Test (PSNT) to help determine N needs.

Figure 2. Generalized nitrogen accumulation curve for annual crops



Pre-sidedress Soil Nitrate Test (PSNT)

The dynamic nature of the N cycle and its sensitivity to weather limits the value of routine, pre-season soil testing for predicting N availability during the season in our humid environment. However, under certain circumstances, in-season soil testing has proven useful. The PSNT, developed by Dr. Fred Magdoff at the University of Vermont in the early 1980's, was originally intended to help estimate the amount of available N for field corn in fields where manure had been applied and/or forage legumes were grown in rotation. Over the last thirty years, research conducted in the Northeast has found the PSNT useful for improving N management of several vegetable crops including sweet corn, peppers, pumpkin, winter squash, and cabbage. The PSNT is most suitable for use with annual crops, which accumulate N rapidly within a single growing season.

The PSNT is especially useful where large amounts of N from mineralization are expected, and the test works best when pre-plant and starter fertilizer N rates are less than about 50 lb N

per acre. PSNT samples are collected about a week before the rapid growth phase (see Figure 2), to provide an indication of how much N has been made available from mineralization. During wet springs with heavy leaching rains, or in sandy soils with rapid losses, the PSNT will also provide some indication of how much N remains in the root zone.

As with all soil testing, information from a PSNT should be used along with the grower's experience and knowledge of the field. Interpretation of the PSNT is also crop-specific. Research in the Northeast has shown that when the soil nitrate N level is above 20-25 ppm there is rarely an economic response to the application of sidedress fertilizer N for sweet corn. Based on research and experience in New England, New Jersey, and New York, a threshold of 25-30 ppm seems appropriate for peppers, tomatoes, butternut squash, cabbage, pumpkin, and probably other long-season vegetable crops. When PSNT values are below threshold levels, the appropriate rate of sidedress N should be determined based on the level of nitrate N reported, previous N application, realistic yield expectation, the field's management history, and growing season conditions. See Table 2 for recommendations on timing of sampling and making sidedressing applications of N based on PSNT for many vegetable crops.

Samples for the PSNT should consist of a well-mixed composite of 10-20 cores or slices of soil to a depth of 12 inches. This is a deeper sample than what is recommended for routine soil sampling. A deeper sample is required for nitrate testing to accurately reflect the concentration in the effective root zone due to its mobility in soil. Avoid sampling fertilizer bands or areas that may have received extra N. About one cup of the composite should be dried to stabilize the nitrate. A good method is to spread a thin layer of the soil on a cookie sheet or aluminum foil to air dry. Use a fan to reduce drying time. Do not place damp samples on absorbent material because it can absorb some of the nitrate. You can skip the drying step if you can deliver the samples to the soil testing lab in less than 24 hours; however, samples should be kept cool. Fields should be sampled for the PSNT about a week before the time when sidedressing is normally done. This should allow adequate time for drying, shipping,

and testing (turnaround time in the lab is about 24 hours) and for you to plan your fertilizer program.

Phosphorus

For the purposes of fertilizer grades and recommendations, phosphorus (P) is measured as phosphate, or P_2O_5 .

The amount of extractable P in a soil should not exceed the optimum soil test range to obtain the most economic return from P applications. To maintain water quality, extractable P should not exceed the *Environmental critical concentration*, which is much higher than the *Optimum* range, to maintain water quality. When extractable P exceeds the *Environmental critical concentration*, the risk of dissolved P loss in subsurface water flow or runoff is significantly increased. This P pollution can stimulate excessive growth of algae in lakes and ponds. When the algae die and their biomass is rapidly decomposed by microorganisms, oxygen levels are reduced below the level needed by fish and shellfish, resulting in large die-offs of aquatic life.

Excessive P amounts in soils are difficult to reduce because vegetable crops remove little P from the soil compared to N or K. For example, Table 4, page 8 shows that sweet corn takes up about 155 lb N per acre and about 105 lb K per acre, but only about 20 lb P per acre. However, many growers apply about 100 lb P per acre annually. This is justified only if soil test P levels are below optimum. If the soil test level for P is above optimum, there is little if any crop response to additional P applications.

Plant uptake of P is extremely slow in cold soils. For this reason, when planting early into soils testing *Optimum* or lower, it is often advisable to apply up to 30 pounds of P_2O_5 as starter fertilizer in a band about 2" below and 2" to the side of the seed when planting, or as a liquid around transplants. Keep in mind that P availability is reduced in alkaline soils (pH >7.3) as it will bind with Ca, becoming unavailable to plants, and in acidic soils (pH <5.5) when it binds with Al, becoming unavailable to plants. Therefore, it is important to first balance the soil's pH with lime applications into the range of pH 6-7 before making P_2O_5 applications.

Table 2. Timing of PSNT and sidedress nitrogen needs of crops¹

CROP	SOIL SAMPLING TIME FOR PSNT	SIDEDRESS LB N PER ACRE ²
Beets	After thinning (2-4 leaves)	30
Cabbage, brussels sprouts, broccoli	2 weeks after transplanting	60
Cauliflower	2 weeks after transplanting	30
Celery	2 weeks after transplanting, again 3-4 weeks later	40 twice, 3-4 weeks apart
Cucumber, muskmelon	Before vines are 6" long	40
Eggplant	3-4 weeks after planting, again 3-4 weeks later	30-50
Lettuce, endive, escarole	2 weeks after transplanting or after thinning (2-4 leaves)	30-50
Pepper	3-4 weeks after planting, again 3-4 weeks later	50, and 40 later at fruit set
Spinach	2-4 leaves, again after first cutting	30
Sweet corn	when plants are 6"-10" tall	60-90
Tomato	3-4 weeks after planting, again 3-4 weeks later	30 twice, 3-4 weeks apart

¹ Adapted from: Rutgers Cooperative Extension Bulletin by J. Heckman, "Soil Nitrate Testing as a Guide to Nitrogen Management for Vegetable Crops"

² If soils have 0-30 ppm nitrate, apply the full sidedress amount recommended. For sweet corn, the threshold is 25 ppm nitrate. Above 30 ppm no additional N is needed and could hurt yields.

Potassium

Potassium (K) is measured as potash (K₂O), similar to the way P is measured as P₂O₅. Crop need for potassium (K₂O) varies considerably as can be seen in Table 4 (page 8). It is important that the soil K plus the applied K is enough to meet crop needs. However, excessive levels should be avoided because K can interfere with the uptake of Ca and Mg (see Cation Exchange Capacity and Base Saturation under Fundamentals of Soil Health and Soil Fertility). K is subject to leaching on sandy soils low in organic matter, so if high amounts are needed, split applications should be used. Very high application rates of K are also known to suppress Mg uptake, and when soil test Mg levels are low, may cause Mg deficiency.

Calcium

Calcium (Ca) is usually supplied in sufficient quantities by liming if appropriate liming materials are chosen (see Soil Acidity, pH, and Liming, page 7). If soil pH is high and Ca is needed, it can be supplied without affecting pH by applying calcium sulfate (gypsum) which contains 19%-23% Ca. Small amounts can also be applied as calcium nitrate fertilizer (19% Ca) or superphosphate (18%-21% Ca). See Table 5, page 12.

Magnesium

Magnesium (Mg) is most economically applied as dolomitic or high-mag limestone (see Soil Acidity, pH, and Liming, page 7). If liming is not needed, Sul-Po-Mag (11% Mg, 22% K) can be used. Blended fertilizer containing Mg can also be ordered.

Micronutrients

Micronutrient deficiencies are rarely observed in New England soils, especially on soils that have a history of compost or manure applications. For this reason little research has been completed calibrating soil tests for micronutrients, and there are no reliable soil test calibration data to interpret soil micronutrient levels and make recommendations for amounts of micronutrients to apply. Most New England labs offer micronutrient soil testing and present results relative to values typically observed in soils analyzed in their laboratory for comparison.

Calibration data for plant tissue analysis are also limited. When a grower suspects a micronutrient deficiency, the recommended procedure is to collect soil and plant tissue samples from areas in the field with good and poor plant growth, and have the samples analyzed using standard methods. A relative comparison of the concentrations of micronutrient in the soil and plant tissue samples will usually allow a diagnosis to be made. Foliar applications of micronutrients may alleviate nutrient deficiencies observed during the season. However, applications of micronutrients to the soil are the better long-term approach to address the rare occurrence of micronutrient deficiencies.

Micronutrient deficiencies are most likely to occur in sandy soils with low organic matter. High soil pH may also bring about micronutrient deficiencies, especially in sandy soils. It may be necessary to maintain pH between 6 and 6.5 to avoid problems in coarse-textured soils with low organic matter. Of all the micronutrients, boron (B) is most likely to be needed in New England to supplement soil levels for vegetable production. Cauliflower, broccoli, cabbage and

beets are most susceptible to “hollow heart” caused by boron deficiency. Boron, copper, zinc and molybdenum have small ranges for optimum soil test values, which means the difference between deficient levels and toxic levels in the soil are small. Be careful with applications of these nutrients to avoid toxic quantities. Some vegetable crops are particularly sensitive to high levels of boron. Sensitive crops should not be planted on fields following crops that have received boron application. Table 3 lists crops according to their sensitivity to boron.

Table 3: Relative Tolerance of Vegetables to Boron

Tolerant	Semitolerant	Sensitive
artichoke	bell pepper	bean
asparagus	broccoli	cucumber
beet	cabbage	garlic
broad bean	cauliflower	Jerusalem artichoke
carrot	celery	lima bean
parsley	corn	pea
spinach	lettuce	
tomato	muskmelon	
	pea	
	potato	
	pumpkin	
	radish	
	sunflower	
	sweet potato	
	turnip	

Adapted from L.V. Wilcox, *Determining the quality of irrigation water*, USDA Agricultural Information Bulletin 197 (1958) and information from Robert Becker, Cornell University.

FUNDAMENTALS OF SOIL HEALTH AND FERTILITY

Soil health (or soil quality) has been defined as the capacity of a soil to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation over a human time scale (thousands of years). Similarly, soil fertility can be viewed as a function of the biological, physical and chemical characteristics of soil.

In more specific terms, a healthy and fertile soil must have: good tilth and drainage, sufficient depth for crop growth, sufficient exchangeable nutrient supply (not excessive or prone to leaching), small population of weeds, insect pests or plant pathogens, large population of beneficial organisms (including microbes), no toxins, and resilience to adverse conditions.

Soil Health

A number of individual soil tests may be used to assess aspects of soil health (including those obtained with routine soil analysis); however, a comprehensive evaluation includes a suite of complementary tests to measure chemical, physical, and biological properties. Researchers at Cornell University evaluated a large number of these measurements for use in Northeastern cropping systems and now offer the most meaningful measurements as part of the Cornell University Soil Health Test. This suite of soil health indicators is designed to provide growers with helpful information about

problems that may limit crop productivity and/or soil performance. Recommendations are provided with the results to help growers address problems that may be identified. More information about the Cornell University Soil Health Test (including sampling protocol, current prices, and submission forms) can be found at <http://soilhealth.cals.cornell.edu/>. Other soil testing laboratories in New England now offer soil health tests. Check with your local lab.

Soil Organic Matter

Soil organic matter (SOM) supports soil health because of the beneficial chemical, physical and biological properties it imparts. SOM increases a soil's ability to hold nutrients by directly increasing cation exchange capacity. SOM also benefits the physical properties of soil by building soil structure and increasing water holding capacity. Finally, SOM supports many of the biological properties of soil health through microbial mineralization of nutrients, development of mycorrhizal relationships with crop roots, and production of sticky substances that hold soil aggregates together.

SOM is composed of materials containing carbon that came from living organisms, including plant and animal remains, bacteria and fungi, etc., in various stages of decomposition. SOM includes humus, which is mostly dead microbes and decomposed organic matter that has reached a relatively stable stage. Native SOM content in soils used for vegetable production in New England is almost always less than 10% and typically in the 2%-6% range. Several factors control the amount of SOM a soil may have. These factors include soil texture and drainage. Well drained, coarse textured soils tend to have lower levels of SOM, due in part to the rapid microbial decomposition rates favored by these soil conditions. In contrast, in loam soils it is reasonable to aim for 4%-6% organic matter (see discussion below on Building Soil Organic Matter). In any case, it is important to maintain SOM because it is typically the most important component of soil for nutrient supply, water holding capacity, cation exchange capacity, and soil structure.

SOM supplies nutrients through the process of mineralization, which is the microbial decomposition of organic compounds into carbon dioxide and their mineral constituents. Soil microbes are most active in warm soils (over 70°F) that are moist, but well aerated, with a pH between 6 and 7 (also ideal conditions for most vegetable crops). Mineralization of nutrients will proceed rapidly under these conditions.

SOM has a large influence on water holding capacity directly by its ability to absorb large amounts of water and indirectly by improving soil structure, which creates more pore space for storage of water as well as larger pores for holding air. Soil structure is enhanced by SOM because, as it decomposes, sticky compounds like gums, carbohydrates, and resins are produced by microorganisms. These gums cement soil particles together into secondary aggregates. The cation exchange capacity of soils is controlled by both clay and SOM content, with both types of particles supplying negatively charged sites that hold cations. In most New England soils, the humus portion of SOM accounts for the vast majority of the cation exchange capacity because soils are typically low in clay content. See also Cation Exchange Capacity and Base Saturation.

Building Soil Organic Matter

Soil Organic Matter (SOM) is in a constant state of flux—additions and losses are simultaneously occurring. To maintain SOM levels, one must reduce the rate of SOM losses while increasing the rate of SOM additions.

SOM can be lost from soil by both wind and water erosion. However, the primary mechanism for SOM loss is microbial decomposition. Soil microbes use SOM as a source of energy and nutrition, converting SOM into carbon dioxide and mineral elements. The rate of microbial decomposition of SOM is controlled by a number of factors including: soil temperature, moisture, aeration (oxygen), and the quality or characteristics of the SOM. The rate of decomposition can be greatly influenced by management. For example, aggressive tillage and cultivation increases aeration and destroys the soil aggregates that protect SOM from microbial decomposition. Reducing tillage and cultivation is an effective management strategy to maintain, or even increase, SOM content (see Reduced Tillage, page 20).

There are a number of ways to increase or maintain SOM. Increasing the quantity of plant residues returned to the soil is one of the most sustainable methods of maintaining or increasing SOM additions. Most vegetables leave little residue in the field and SOM will usually decrease if only vegetable residues remain in fields. However, significant amounts of biomass can be added to the soil by including cover crops in a rotation. Although cover crops can add enough biomass to maintain SOM, it is difficult to increase SOM with most cover crops. Sod forming crops included in the rotation, however, can increase SOM. Another more rapid and direct method of increasing SOM is by adding organic amendments such as organic mulch and compost. While the application of organic amendments can rapidly increase SOM, extractable soil phosphorous (P) concentrations must be monitored to avoid excessive applications (see Fertilizers and Soil Amendments, page 13).

Cation Exchange Capacity and Base Saturation

Cation exchange capacity (CEC) is a measure of the soil's ability to retain and supply nutrients, specifically the positively charged nutrients called cations. These include calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), ammonium (NH_4^+), and many of the micronutrients. Cations are attracted to negatively charged surfaces of clay and organic particles called colloids. CEC is reported as milli-equivalents per 100 grams of soil (meq/100g) or as centimoles of charge per kilogram (cmole+/kg). CEC can range from below 5 meq/100g in sandy soils low in organic matter to over 20 meq/100g in finer textured soils and those high in organic matter. Low CEC soils are more susceptible to cation nutrient loss through leaching, and may not be able to hold enough nutrient cations for a whole season of crop production.

The cations Ca^{++} , Mg^{++} , K^+ , hydrogen (H^+) and aluminum (Al^{+++}) account for the vast majority of cations adsorbed on the soil colloids in New England soils. It is important to note that H^+ and Al^{+++} are not plant nutrients. Both H^+ and Al^{+++} are considered acidic cations because they tend to lower soil pH while Ca^{++} , Mg^{++} , and K^+ are considered basic cations and have little to no influence on soil pH. If all the cations are basic and none are acidic, there would be a 100% base

saturation and the soil pH would be close to 7 or neutral. In acid soils there are acidic cations adsorbed on the soil colloids (called exchangeable acidity) and the percent base saturation is less than 100. A soil with a pH between 6.5 and 6.8 will typically have a base saturation of 80%-90%.

Soil Acidity, pH, and Liming

One of the most important aspects of nutrient management is maintaining proper soil pH, a measure of soil acidity. A pH of 7.0 is neutral, less than 7.0 is acidic, and greater than 7.0 is alkaline. Most New England soils are naturally acidic and need to be limed periodically to keep the pH in the range of 6.5 to 6.8 ideal for most vegetable crops. Scab-susceptible potato varieties are an exception, but some lime may still be needed to maintain the recommended pH of 5.0-5.2. When the soil is acidic, the plant availability of nitrogen (N), phosphorus (P), and potassium (K) is reduced and there are usually low amounts of calcium (Ca) and magnesium (Mg) in the soil. In contrast, most micronutrients are more soluble and are therefore more available to plants. Under very acidic conditions aluminum (Al), iron (Fe), and manganese (Mn) may be so soluble they can reach toxic levels. Soil acidity also influences soil microbes, which decompose organic matter and recycle crop nutrients. For example, when soil pH is low (below 6.0), bacterial activity is reduced and fungal activity increases. Acidic soil conditions also reduce the effectiveness of some pesticides.

The most effective way to manage soil acidity is to apply agricultural limestone. The quantity of lime required is determined by the target pH (based on crops to be grown) and the soil's buffering capacity, measured in a soil test. Buffering capacity refers to the soil's tendency to resist change in pH. Soil pH is only a measure of active acidity, the concentration of hydrogen ions (H^+) in soil solution. When lime is added to a soil, active acidity is neutralized by chemical reactions that remove hydrogen ions from the soil solution. However, there are also acidic cations (H^+ and Al^+) adsorbed on soil colloids (see CEC, previous section) that can be released into the soil solution to replace those neutralized by the lime. This is called reserve acidity. Clays and soils high in organic matter have the potential for large amounts of reserve acidity. These soils are said to be well-buffered. To effectively raise the soil pH, both active and reserve acidity must be neutralized. Soil test labs determine buffering capacity and lime requirement by measuring or estimating the reserve acidity.

The neutralizing power of lime is determined by its calcium carbonate equivalence. Suppliers can tell you the calcium carbonate equivalence of the lime you are purchasing. Recommendations are based on an assumed calcium carbonate equivalence of 100. If your lime is lower than 100, you will need to apply more than the recommended amount, and if it is higher, you will need less. To determine the amount of lime to apply, divide the recommended amount by the percent calcium carbonate equivalence of your lime and multiply by 100. Wood ash is another amendment that may be used to manage soil acidity. The calcium carbonate equivalence of wood ash is typically around 50%, but it can vary widely. If purchasing wood ash from a supplier, they will provide a recent analysis. Otherwise the wood ash should be submitted to a lab offering lime analysis to determine the calcium carbonate equivalence.

The speed with which lime reacts in the soil is dependent on particle size and distribution in the soil. To determine fineness, lime particles are passed through sieves of various mesh sizes. A U.S. Standard 10-mesh sieve has 100 openings per square inch while a 100-mesh sieve has 10,000 openings per square inch. Lime particles that pass through a 100-mesh sieve are very fine and will dissolve and react rapidly (within a few weeks). Coarser material in the 20- to 30-mesh range will react over a longer period, one to two years or more. Agricultural ground limestone contains both coarse and fine particles. About half of a typical ground limestone consists of particles fine enough to react within a few months, but to be certain you should obtain a physical analysis from your supplier. Super fine or pulverized lime is sometimes used for a "quick fix" because all of the particles are fine enough to react rapidly.

Lime will react most rapidly if it is thoroughly incorporated to achieve intimate contact with soil particles. This is best accomplished when lime is applied to a fairly dry soil and disked in (preferably twice). When spread on a damp soil, lime tends to cake up and doesn't mix well. A moldboard plow has little mixing action, therefore, disking is preferred.

Besides neutralizing acidity and raising soil pH, lime is also an important source of Ca and Mg for crop nutrition. It is important to select liming materials based on Ca and Mg soil content with the aim of achieving sufficient levels of each for crop nutrition. If the Mg level is low, a dolomitic lime (high magnesium lime) should be used; if Ca is below optimum, a calcitic (low-Mg lime) should be used.

Nutrient Recommendations

Normally it is not necessary to supply all the nutrient needs of a crop from fertilizer alone, because the soil already contains some quantity of nutrient elements available for crop growth. It is necessary to test the soil to determine its nutrient status, because only then can you determine the additional amounts of appropriate fertilizer materials to apply. Frequently, growers apply more fertilizer than the crop can use and the excess, especially nitrogen, is leached from the root zone into groundwater.

The "Plant Nutrient Recommendations" tables in each crop section can be used to determine nutrient needs based on soil test results. Read the section on Soil Testing to better understand nutrient recommendations.

In general, the goal should be to maintain nutrient elements within the optimum range as reported on the soil test. When nutrient levels are within this range, the needs of most crops will be met. If levels are *below optimum* (*low* or *medium*), most crops would benefit by adding the appropriate nutrient(s) to increase levels to *optimum*. However, if levels are at *above optimum* (*very high*) levels, there will be no additional benefit and excess levels may reduce crop yield or quality and may cause environmental harm. This happens in fields where soil testing was not used to monitor fertility levels or when nutrients are applied even when soil levels are sufficient. When a nutrient is above optimum levels it should not be included in any amendments until the excess is taken up by crops. It may be wise to temporarily stop applying compost until nutrient levels are in the desired range. This is a practical way to manage nutrient levels if small to moderate amounts of mixed crops are to be grown.

If a significant acreage of a particular crop is to be grown, fertilizers should generally be tailored to the specific needs of that crop, based on the amounts of nutrients that the crop is

expected to remove during the growing season (see Table 4). If the soil tests indicate that a nutrient is high/optimum it is likely that the soil will supply enough to meet the crop's

Table 4: Approximate Nutrient Removal by Selected Vegetable Crops.

Vegetable		Yield per acre ¹	Nutrient removal, lb/acre				
			N	P ₂ O ₅	K ₂ O	Ca	Mg
Snap beans	Total	250 bu	30	20	35	7	3
Broccoli	heads	5 tons	20	2	45		
	other		145	8	165		
	Total						
Cabbage	Total	20 tons	125	30	130	28	10
Carrots	roots	25 tons	80	20	200		
	tops		65	5	145		
	Total		145	25	345		
Cauliflower		6 tons	45	18	43	4	3
Celery	tops	50 tons	170		380		
	roots		25		55		
	Total		195	80	435	110	27
Cucumbers		24 tons	100-200	33-72	100-400		
Eggplant		16 tons	207	46	34		
Kale		10 tons	125	30	110	50	10
Lettuce		15 tons	75	35	150	13	5
Muskmelons	fruit	11 tons	95	17	120		
	vines		60	8	30		
	Total		155	25	150		
Onions	bulb	20 tons	110	20	110	12	14
	tops		35	5	45		
	Total		145	25	155		
Peppers	fruits	12 tons	137	52	217		
Potatoes, White	tubers	300 cwt	90	45	160		
	vines		60	20	60		
	Total		150	65	220		
Potatoes, Sweet	roots	15 tons	75	55	160		
	vines		35	5	280		
	Total		110	60	440	10	15
Spinach		10 tons	100	25	100	24	10
Squash, Summer		10 tons	32	12	56		
Squash, Winter		6 tons	12	10	58		
Sweet Corn	ears	250 cr.	55	8	30		
	stalks		100	12	75		
	Total		155	20	105		
Tomatoes	fruit	30 tons	110	48	180	15	15
	vines		90	30	100	24	21
	Total		200	78	280	39	36

¹ These are assumed yields. Actual yields may vary depending on weather and cultural practices. Adjust nutrient removal rates accordingly. To convert to volume or count yield units see Table 15: Approximate Yields, page 37.

needs. However, many growers will apply enough of the nutrient to replace what is removed by the crop. If the test level is above optimum/very high, additional applications should normally be avoided unless the crop has an unusually high demand for a specific nutrient. Occasionally, nutrient applications may exceed the soil test recommendation or the expected average removed by the crop (Table 4) because a particular cultivar is considered a heavy feeder, such as long season Russet potatoes. Or, for example, a large crop of tomatoes can be expected to remove a large amount of potassium and it may be justified to apply some of this nutrient even if the soil test indicates a level somewhat *above optimum*. The nutrient recommendation tables for each crop have been developed on this basis of expected crop removal. This can also be a practical way to determine nutrient needs of high value crops, even when they are grown on a small scale. It is important to keep in mind that many factors can limit crop yield potential, and that simply adding more nutrients will not address any issues beyond nutrient deficiency.

Removal of Nutrients from the Soil

Table 4 lists amounts of certain nutrient elements that are removed by vegetable crops. It includes both the amounts removed by harvest and those that remain in crop residue and are returned to the soil. These figures for crop removal should be considered approximate. They can be used as a basis for adjusting your own application rates up or down on a trial basis. Keep in mind that nutrient removal varies with factors such as soil moisture, temperature, and pH. Plants can absorb large amounts of a nutrient if it is in abundance; but this may not increase yield. Excess levels of some nutrients can reduce the yield and/or quality of some crops.

Nutrients that are relatively immobile in the soil, such as phosphorus, calcium, magnesium and the micronutrients, are not all extracted by plants because the roots do not come in contact with all of the nutrients. This is especially true of certain vegetables that have small or sparse root systems. Most of the phosphorus applied to the soil becomes fixed in a form unavailable to plants. For these reasons, it is necessary to provide some excess amounts of nutrients, when soil test levels are below the optimum range, and why rates sufficient to replace the amount removed by crops are sometimes recommended for soils that test in the optimum range.

NUTRIENT MANAGEMENT REGULATIONS

Several states in New England have nutrient management regulations that impact vegetable production practices. The EPA began regulating municipal waste water treatment facilities to manage water pollution, and more recently, regulations have gone in place to regulate non-point source pollution such as that coming from fertilizer or manure applications on agricultural fields. Below is a list of states with regulations and recommendations on how to comply.

Maine: Regulations for crop farms require the development of a nutrient management plan (NMP) if a farm is importing more than 100 tons of manure or regulated residuals annually. The nutrient management plan must address storage and utilization of manure and off-farm nutrients on land to which the regulated residuals or manure are applied. The NMP must include or provide for minimum distances between manure storage, stacking and spreading areas and property lines and surface water based on site-specific factors

determined to be effective for controlling runoff and for preventing contamination of surface water. The NMP must include soil test reports for each field where manure or other crop nutrients will be applied, and soils must be tested for each field at least every 5 years. For each field, the NMP must show the calculation of nutrients required to grow the specific crop. The producer may write his/her own plan, but it must be approved by a Maine certified nutrient management planner licensed through the Nutrient Management Office. To find a licensed nutrient management planner, contact: **Mark F. Hedrich**, Nutrient Management Program Manager, Maine Department of Agriculture, Conservation and Forestry, Division of Animal & Plant Health, 28 State House Station, Augusta, Maine 04333; 207-287-7608; mark.hedrich@maine.gov

New Hampshire: Best Management Practices (BMPs) for Agriculture are prepared by the Agricultural Best Management Practices Task Force and the USDA Natural Resources Conservation Service (NRCS) in Durham, NH and provides a guide for growers for handling manure, agricultural compost and chemical fertilizer. There is not a law that explicitly requires growers to follow them; however, it is in the producers' best interest to follow these BMPs as they provide protection from nuisance allegations. State law under RSA 431:35 requires the New Hampshire Department of Agriculture, Markets & Food to respond to complaints involving the mismanagement of manure, agricultural compost and chemical fertilizer. Copies of the BMP manual are available to producers as a tool, but the NH Department of Agriculture, Markets & Food does not have the authority to enforce the implementation. A copy of the manual can be found here: <http://agriculture.nh.gov/divisions/regulatory-services/nutrient-management.htm>

Vermont: All farms must comply with the Required Agricultural Practices (RAPs) effective since July, 2017. The RAPs are practices and management strategies to which all types of farms must be managed to reduce the impact of agricultural activities to water quality. These standards are intended to improve the quality of Vermont's waters by reducing and eliminating cropland erosion, sediment losses, and nutrient losses through improved farm management techniques, technical and compliance assistance, and where appropriate, enforcement. The RAPs establish nutrient, manure, and waste storage standards, make recommendations for soil health and establish requirements for vegetated buffer zones and livestock exclusion from surface water. The RAPs also establish standards for nutrient management planning and soil conservation. Full text of the RAPs regulations may be found on the Vermont Agency of Agriculture, Food and Markets here: <https://agriculture.vermont.gov/rap>. Questions regarding these regulations should be directed to the Vermont Agency of Agriculture, Food and Markets, Water Quality Division, AGR. WaterQuality@Vermont.gov, (802) 828-2431.

Massachusetts: In 2012, the Massachusetts Legislature passed Chapter 262, An Act Relative to the Regulation of Plant Nutrients. The text of the enabling legislation can be found at: <https://malegislature.gov/Laws/SessionLaws/Acts/2012/Chapter262>. The Act requires the Department of Agricultural Resources (MDAR) to promulgate state-wide regulations to ensure that plant nutrients are applied in an effective manner to provide sufficient nutrients for plant growth while

minimizing the impacts of the nutrients on water resources in order to protect human health and the environment. The Act also requires that these regulations are consistent with UMass Extension's educational and outreach materials relative to nutrient management and fertilizer, which may be found here: <https://ag.umass.edu/resources/agriculture-resources/umass-extension-nutrient-management>. In response to the Act, MDAR developed regulations entitled "330 CMR 31.00: Plant Nutrient Application Requirements for Agricultural Land and Land Not Used for Agricultural Purposes" (<http://www.mass.gov/eea/agencies/agr/pesticides/plant-nutrient-management.html>). The regulation gives MDAR state-wide authority to regulate and enforce the registration and application of plant nutrients including, but not limited to, fertilizer, manure and micronutrients. The Cape Cod Commission, Martha's Vineyard Commission, and Nantucket Commission have the option to adopt their own ordinances in regard to nutrients and fertilizers, but they cannot be less restrictive than the state regulation.

Connecticut: Currently there are no nutrient management regulations affecting vegetable farmers in CT. There is a Phosphorous Law (CT PA-1255) but it primarily affects wastewater treatment facilities and homeowners who may only apply P if a soil test shows a need and not during winter months.

Rhode Island: No regulations of nutrient applications are in place in RI, however, on a case by case basis (and rarely at that) regulation may occur as part of a response to an environmental violation, for example, a consent agreement resulting from water quality impairment.

SOIL TESTING

Routine soil analysis is the most accurate way to determine lime and fertilizer needs. The shotgun approach to nutrient management, applying all nutrients annually whether needed or not, is neither practical nor economical. Vegetable growers must know the nutrient status of the soil and then match application rates to crop needs. This is important to achieve optimum yield and quality, to maximize return on investment, and to limit nutrient losses to the environment.

Soil Test Methods

Soil test methods used for vegetable production are designed to provide a measurement of lime requirement and nutrient availability. Soil testing labs use different methods and it is best to select a lab using analytical methods appropriate for New England soils that provide soil test interpretations based on field correlation and calibration under local conditions. A list of New England soil test laboratories is provided at the end of this section. In New England, routine soil analysis typically includes a measure of extractable phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), plus several of the micronutrients (e.g., boron, manganese, zinc, copper, and iron). In addition to routine soil analysis, other tests and analytical services are available including: soil organic matter, soluble salts (conductivity), Pre-sidedress Soil Nitrate Test (PSNT), plant tissue analysis, manure and compost analysis, and irrigation water testing.

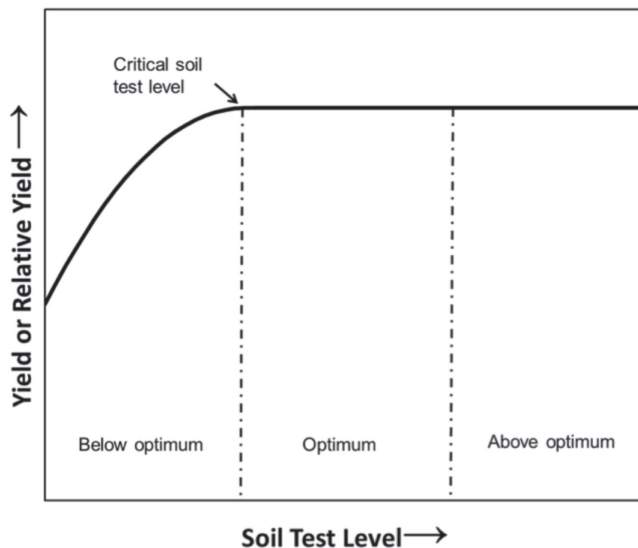
The appropriate soil test methods for a given region are selected based on soil characteristics and climate. Different analytical procedures can result in vastly different results. This is especially true of the different extraction solutions used to estimate a soil's nutrient supply. The two extraction solutions used in New England are the weak acid modified Morgan extract and the strong acid Mehlich 3 extract. These are both universal extraction procedures, meaning they are used to determine all major nutrients and many of the micronutrients simultaneously. Most New England Land Grant University labs (ME, VT, MA, and CT) use the weak acid modified Morgan extract. University of New Hampshire uses the strong acid Mehlich 3 extraction solution. A saturated media test using water as an extractant is used to measure nutrient availability in greenhouse potting media and in some cases, high tunnel soils. See Soil Testing Labs in New England (page 12) for contact information.

The quantity of extractable nutrients may be reported in different units. Some labs report the concentration of nutrients in ppm (parts per million) which is equivalent to mg/kg (weight basis) or mg/dm³ (volume basis). Other labs report nutrient values in lb/acre (weight per area basis). **Nutrient concentration in ppm can be converted to lb/acre by multiplying by 2.** This is based on the assumption that there are approximately 2,000,000 lb of soil in the surface 6 inches of one acre. Differences in reporting units are important to be aware of, but they are of little consequence to our interpretation of soil test results. Soil test results only provide an index of nutrient supply that must be interpreted based on correlation and calibration data developed by nutrient response research in local soils. It is important to understand what the nutrient interpretations mean.

Soil Test Interpretation

Soil test results are of little value without an appropriate interpretation. To be useful, extractable nutrient values must be shown to relate to: 1) the soil's ability to supply that nutrient to crops (correlation); and 2) crop response to application of that element (calibration). Figure 3 illustrates the conceptual relationship between soil test level and yield. This relationship is determined by conducting nutrient response research, under local conditions with representative soils ranging from deficient to adequate for each nutrient of concern. These data form the foundation of our interpretation of soil test results. The exact relationship between soil test level and crop response to different nutrients may vary considerably, but the general shape of the response curve is relatively consistent. At low soil test levels, yield is limited by a lack of the nutrient. As the soil test level increases, yield increases until a point where the nutrient is no longer limiting and the curve levels out; this point is known as the critical soil test level. The critical soil test level is defined as the extractable nutrient concentration in soil above which an economic yield (or quality) response to added nutrient is unlikely. Nutrient levels are considered sufficient when the concentration is just above the critical soil test level. This is known as the *optimum* soil test range. Soil test values are interpreted based on how they compare to the critical soil test level and optimum range.

Figure 3. Conceptual relationship between soil test level and crop yield or relative yield. The critical level is defined as the soil test level for a given nutrient above which there is a low probability to a response addition of that fertilizer.



Soil Sampling

A critical step in soil testing is sample collection. It is important to obtain a representative sample; a poor sample may result in erroneous soil test results and poor recommendations. The first step is to determine the area that will be represented by the sample. Soil physical appearance, texture, color, slope, drainage, and past management should be similar throughout the area. It may be helpful to draw a map of the farm and identify areas where you will sample separately. Using a clean bucket and a spade, auger, or sampling tube collect at least 12-15 subsamples to a depth of 6-8 inches from random spots within the defined area and place them in the bucket. This may be accomplished by walking a zig-zag pattern across the sampling area and collecting a subsample periodically. Avoid sampling field edges, old fence rows, areas where manure or lime were stockpiled, and other non-representative areas. Next, break up any lumps or clods of soil, remove stones and plant debris, and thoroughly mix subsamples in the bucket. This step is very important, because only a few tablespoons of your sample will actually be used for testing. Once the sample is thoroughly mixed, scoop out approximately one cup of soil and spread on a clean piece of non-adsorbent paper to air-dry (brown paper bags work great). Once the sample is dry, place it in a labeled container provided by the lab (or a zip lock bag), and complete a sample submission form. For each sample, indicate the crop to be grown, recent field history and any concerns.

Soil pH and extractable levels for certain nutrients (e.g., P and K) vary throughout the year. While the seasonal fluctuation is not typically large enough to significantly influence interpretation and recommendations, it can make it difficult to compare soil test values from the same field over time. For this reason, it is a good idea to be consistent about timing of sample collection from one year to the next. Although soil samples can be taken any time, many prefer to take samples in late summer or fall because this allows time to apply any needed lime, plan a fertility program and order materials well in advance of spring planting. Avoid sampling

when the soil is very wet or within six to eight weeks after a lime or fertilizer application. Routine soil analysis should be conducted once every two to three years.

Soil Test Recommendations

Nutrient recommendations are determined by soil test results; however, even when two labs use the same methods and generate equivalent results, their nutrient recommendations may differ. These disparities arise due to differences in soil test interpretation and recommendation philosophies. Over the years, three basic philosophies have emerged. These include the *sufficiency approach*, the *build and maintain approach*, and the *base cation saturation ratio (BCSR) theory*. Both the *sufficiency approach* and the *build and maintain approach* follow the general concept that there are definable critical levels of nutrients in soil, and that below this level crops are likely to respond to additional nutrients applied. When nutrient concentrations are in the optimum range, just above the critical level, there is a low probability of crop response to the addition of that nutrient. With the build and maintain approach, fertilizer recommendations are made with the goal of building the soil's nutrient levels into the optimum range, then maintaining these levels by applying nutrients at rates that approximate crop removal. The sufficiency approach is a more conservative philosophy where nutrient recommendations are intended to meet crop needs, not build soil fertility. No nutrients are recommended above the critical soil test level. The sufficiency approach is designed to "feed the crop" while the build and maintain approach is designed more to "feed the soil." In theory, the sufficiency approach is a more profitable system since fertilizer is only applied when there is likely to be an economic return. However, in practice the sufficiency approach is also more risky due to the inherent uncertainty associated with soil testing.

The third philosophy, the *BCSR theory*, promotes the idea that maximum yields can only be achieved by creating a balanced ratio of calcium (Ca), magnesium (Mg), and potassium (K) in the soil. The concept is rooted in work conducted by Dr. Firman Bear and his colleagues at the New Jersey Agricultural Experiment Station in the 1940's. Dr. Bear's work showed that the luxury consumption of costly fertilizer K by alfalfa could be reduced by applying high rates of relatively low cost Ca (as ground gypsum or calcitic lime). Later publications by Bear and his colleagues suggested that there were ideal ratios of Ca, Mg, and K; however, they provided no data to support these claims so it is unclear how they were developed.

Around the same time, Dr. William Albrecht and his colleagues at the University of Missouri also began to investigate the BCSR theory. Based on this work, Albrecht suggested a balanced soil should have a cation saturation of 60%-75% Ca, 10%-20% Mg, and 2%-5% K. It is unclear how Albrecht derived these values, and further careful evaluation of the work a number of years later revealed several fundamental flaws in the methods used. A number of soil scientists have evaluated the BCSR theory over the years and their work has failed to support claims of BCSR theory and has illustrated that using it to manage soil fertility results in inefficient use of both capital and natural resources. Despite this fact, a number of unsubstantiated claims regarding the importance of attaining an ideal BCSR,

especially pertaining to the importance of very specific Ca:Mg ratios, continue to be promoted. There are no research data that support these claims.

At one time, many private labs and a few public labs used the BCSR concept to interpret soil test results and make nutrient recommendations. As the body of research evidence illustrating the flaws of the BCSR concept grew, most private labs and essentially all of the public labs abandoned the system. Most of the guidelines developed by Land Grant Universities and used by both public and private soil test labs follow a combination of the sufficiency and build and maintain approaches, the goal being to provide adequate, but not excessive, levels of essential nutrients to promote healthy plant growth. Nutrient recommendations provided in this Guide are a reflection of this compromise. The nutrient guidelines are intended to help growers optimize crop yield and quality, maximize return on fertilizer investment, and minimize nutrient losses to the environment.

The nutrient recommendation tables in this Guide are applicable to the New England soil test results given as *very low*, *low*, *optimum* (medium or high), and *above optimum* (very high or excessive). Table 5 provides a brief interpretation of each of these categories. Generally, nutrients should be in the optimum range for good yield and quality. When levels are below the optimum range (very low or low), the addition of more of the nutrient will usually improve production and provide a return on fertilizer investment. Nutrient recommendations are intended to meet crop needs and provide enough to slowly (several years) build soil test levels to the optimum range. When soil test levels are in the optimum range, crop response to application of that nutrient is unlikely, but some amount may be recommended to maintain soil tests levels by replacing a portion of crop removal. In the nutrient recommendation tables for each crop listed in the guide, this is indicated by a range such as 0-50 lb per acre. Crops and even cultivars of the same species vary in their uptake and removal of nutrients and this is accounted for in the nutrient recommendations. If a nutrient is in the Above optimum range, crop response is very unlikely and application of that nutrient is generally unjustified. It is important to keep in mind that factors other than nutrients may limit crop growth, and simply adding more nutrients

will not improve yield. To optimize yield and maximize response to fertilizer nutrients, sound agronomic practices must be used (e.g., crop rotation, timely planting and harvest, pest control, and irrigation).

Plant Tissue Testing

An additional tool that can be used for long season crops such as eggplant, pepper, potato, tomato, squashes, sweet corn, and pumpkin is plant tissue analysis. While leaf tissue laboratory analysis can be used to verify symptomatic deficiencies in any nutrients, it can also be used to detect sufficiency levels of critical nutrients such as N, P, K, Ca and Mg. If performed early enough in the season, corrections can be made by topdressing, side dressing, or fertigation. Prior to making nutrient corrections, other potential issues should be addressed first, such as incorrect pH, inadequate soil moisture, root disease or insect infestation. Leaf tissue analysis requires collecting an adequately sized sample (from all over a planting) of whole leaves from designated locations in the plant canopy. These locations vary among crop species and specific sampling and handling instructions are available from university and private laboratories. For the purpose of comparison, laboratory reports will also present results in tabular form alongside reference sufficiency ranges of nutrient concentrations for the crop tested. Nutrient status of some crops can also be determined using laboratory testing of whole leaf petioles, and for nitrate-N and K, it is possible to test petiole sap in-field using a portable meter.

Soil Testing Labs in New England

Connecticut:

Soil Nutrient Analysis Lab
6 Sherman Place, Unit 5102, Storrs, CT 06269-5102
Telephone: 860-486-4274
Website: <http://www.soiltest.uconn.edu/>
Email: soiltest@uconn.edu

Gregory Bugbee, State Laboratory
The Connecticut Agricultural Experiment Station
123 Huntington St., P.O. Box 1106, New Haven, CT 06504
Telephone 203-974-8521
Website: <http://www.ct.gov/caes/cwp/view.asp?a=2836&q=378206>
Email: Gregory.Bugbee@po.state.us

Category	Interpretation
Very Low	Soil test level is well below optimum. Very high probability of crop response to additional nutrients. Substantial amounts of additional nutrients required to achieve optimum yield. Fertilizer rates based on crop response and are designed to gradually increase soil nutrient levels to the optimum range over a period of several years.
Low	Soil test level is below optimum. High probability of crop response to addition of nutrients. Moderate amounts of additional nutrients needed to achieve optimum yield. Recommendations based on crop response and are intended to gradually increase soil nutrient levels to the optimum range.
Optimum	Most desirable soil test range on economic and environmental basis. For most crops, low probability of crop response to addition of nutrients. To maintain this range for successive years, the nutrients removed by crops must be replaced.
Above Optimum	The nutrient is considered more than adequate and will not limit crop yield. At the top end of this range, there is the possibility of a negative impact on the crop if nutrients are added.
Environmental Critical Level	This soil test level is independent of crop response and, due to environmental concerns, is only defined for soil test P. This P concentration is associated with elevated risk of P loss in leachate and runoff at concentrations high enough to impair surface water quality. No P should be applied and steps should be taken to minimize losses from leaching and runoff.

Maine:

The Analytical Laboratory and Maine Soil Testing Services
 5722 Deering Hall, Room 407
 Dept. Plant & Soil & Environmental Sciences, Orono, Maine 04469-5722
 Telephone: 207-581-3591
 Website: <http://anlab.umesci.maine.edu/>
 Email: hoskins@maine.edu

Massachusetts:

UMass Soil & Plant Tissue Testing Laboratory
 203 Paige Lab
 161 Holdsworth Way
 University of Massachusetts, Amherst, MA 01003
 Telephone: 413-545-2311
 Website: <http://soiltest.umass.edu/>
 Email: soiltest@umass.edu

New Hampshire:

UNH Cooperative Extension Soil Testing Program
 Spaulding Life Science Center, Room G28
 38 Academic Way, Durham, NH 03824
 Telephone: 603-862-3200
 Website: <https://extension.unh.edu/programs/soil-testing-services>
 Email: soil.testing@unh.edu

Vermont:

UVM Agricultural & Environmental Testing Laboratory
 262 Jeffords Hall, 63 Carrigan Drive, UVM, Burlington, VT 05405-1737
 Telephone: 802-656-3030
 Website: http://pss.uvm.edu/ag_testing
 Email: AgTesting@uvm.edu

Private:

Woods End Research Lab, Inc.
 290 Belgrade Road, P.O. Box 297, Mt. Vernon, ME 04352
 Website: www.woodsend.org
 Email: lab1@woodsend.org

FERTILIZERS AND SOIL AMENDMENTS

There are many ways to provide nutrients to meet crop needs and to build up a reservoir of nutrients in the soil. This section provides an overview of fertilizers and amendments commonly used in vegetable production systems.

Fertilizer recommendations for vegetable crops should be made in conjunction with a soil test report. Repeated use of the same amendments without regard to soil test level will likely lead to excess levels of certain elements, nutrient imbalances, poor return on fertilizer investment, and increased risk of nutrient losses to the environment.

Fertilizers

Fertilizer grades refer to the guaranteed percentages of plant nutrients. The ratio refers to the proportion of nitrogen (N), phosphate (P₂O₅) and potash (K₂O) in the fertilizer. For example, the grade is 5-10-5, and the ratio is 1-2-1. High analysis fertilizers are those with grades such as 20-20-20, 35-0-0 or 0-46-0, and are more economical to use on the basis of price per pound of nutrient.

Liquid starter fertilizers are materials that are completely water soluble and are high in phosphorus content such as 16-32-16, 10-52-17 or 9-45-15. These materials are used at the time of transplanting. Dry starter fertilizer can be banded at the time of seeding. The band is normally placed 2" below

and 2" to the side of the seed. When using either dry or liquid starter fertilizer, follow label directions because an excess of starter could burn seeds and young seedlings. Starter fertilizer promotes early and rapid growth that leads to greater yields with certain crops such as tomato, pepper, and melon. See individual crops for rates.

Table 6, "Plant Nutrient Content of Various Fertilizer Sources" lists many fertilizers commonly used for vegetable cropping systems. Similar information for fertilizers and amendments commonly used in certified organic cropping systems are provided in the section entitled Guidelines for Organic Fertility Management (Table 10, page 19).

Manure

Animal manure is an excellent source of nutrients and organic matter. Many of the nutrients, especially nitrogen, are readily available from fresh livestock manure. Nutrient content varies by animal species, their diets and the form of their manure. About half of the nitrogen in fresh dairy manure and 75% of the nitrogen in poultry manure is in the form of ammonia. Ammonia is subject to loss through volatilization if not incorporated immediately after spreading. In the soil, ammonia is converted to nitrate and is available for plant use or is directly absorbed as ammonium. However, nitrate is subject to leaching and large applications (more than 40 tons per acre dry or 20,000 gallons per acre liquid) should generally be avoided. There are times when readily available nitrogen is needed, but many people prefer to compost manure before field application (see Compost section below). This stabilizes the nitrogen. Manure can be mixed with other materials for composting. Manure samples can be analyzed by the Universities of Maine and Vermont Laboratories. Manure carries pathogens that are of concern to human health. Uncomposted manure should not be applied within 90 or 120 days of harvesting vegetable crops, depending on whether or not the edible part of the crop has contact with the soil. Manure application rates are now regulated in many New England States (see Nutrient Management Regulations, page 9).

Nitrogen in manures and other waste products: The N content of manures is highly variable. Differences are due to the species of animal, the animal's age and diet, the moisture content of the manure, handling and storage, and the amount of bedding in the manure. The N fertilizer equivalent of a manure varies not only with the total N content of the manure, but also with the timing and method of manure application. The values in Table 7 (page 15) are based on analyses of Vermont manures as well as published data from other states. If specific manure analysis data is not available, growers should estimate N credits using these or other book values. The time elapsed between spreading and incorporation of manure is also important. About half of the N in dairy manure and three quarters of the N in poultry manure is in the form of ammonium (NH₄), which easily turns to ammonia gas (NH₃) and is volatilized (lost to the air). The longer that manure is left on the soil surface, and not incorporated, the greater NH₃ volatilization losses become (Table 7a). Broadcast application of slurry manure without incorporation should always be avoided because this method increases air contact and allows time for all ammonia to be lost. Research has shown that in reduced or no-till fields

where manure must be surface applied without incorporation, ammonia can be best conserved if applied during cold temperatures, low wind speeds and especially to a growing cover. A growing cover also reduces manure run-off and leaching losses. **NOTE: Manure often contains human pathogens. Serious illness has occurred from eating produce where fresh manure was applied without an adequate waiting period (see Produce Safety, page 39).**

Previous manure applications: Up to 50% of the total N in cow manure is available to crops in the year of application. Between 5% and 10% of the total N applied is released the year after the manure is added. Smaller amounts are furnished in subsequent years. The quantity of N released the year after a single application of 20 tons per acre of cow manure is small (about 15 lb N per acre). However, in cases where manure has been applied at high rates (30-40 tons per acre) for several years, the N furnished from previous manure increases substantially. The buildup of a soil's

capacity to supply N resulting from previous applications of manure has important consequences for efficient N management, including: 1) The amount of fertilizer N needed for the crop decreases annually; and 2) If all the crop's N needs are being supplied by manure, the amount of manure needed decreases yearly.

With poultry manure (as compared with manure from cattle) a higher percentage of the total N in the manure is converted to plant-available forms in the year of application. Consequently, there is relatively less carry-over of N to crops in succeeding years. This does not mean, however, that there is never any carry-over of N from poultry manure applications. If excessive rates of poultry manure (or commercial N fertilizers) are used, high levels of residual inorganic N, including nitrate (NO₃), may accumulate in soil. High levels of soil nitrate in the fall, winter and spring have the potential to pollute groundwater and coastal seawater.

Table 6: Plant Nutrient Content of Various Fertilizer Sources (% by weight)

Fertilizer Source Material	Total Nitrogen N%	Available Phosphoric Acid P ₂ O ₅ %	Water Soluble Potash K ₂ O %	Combined Calcium Ca %	Combined Magnesium Mg %	Combined Sulfur S %
Ammonium sulfate	21	0	0	0	0	23
Ammonium nitrate	34	0	0	0	0	0
Anhydrous ammonia	82					
Calcium nitrate	15			19		
Calcium ammonium nitrate	27					
Diammonium phosphate	18	46				
Monoammonium phosphate	11	48				
Epsom salts					10	13
Granulated Sulfur						90-92
Gypsum				19-23		15-18
Muriate of potash			60			
Nitrate of potash	13		44			
Nitrate of soda-potash	15		14			
Nitrate of soda	16					
Superphosphate		20		18-21		11
Sul-po-mag			22		11	23
Sulfate of potash			50			17
Triple superphosphate		44-46		13		
Urea	45-46					

Table 6a: Conversion Factors for Boron Nutrient Sources

Fertilizer Source Material	Boron content, %	Pounds of Material Required to Supply One Pound of Boron
Fertilizer Borate Granular ¹	14.30 (B)	7.0
Fertilizer Borate-48	14.91 (B)	6.7
Solubor	20.50 (B)	4.9
Fertilizer Borate-68	21.13 (B)	4.7

¹ Best for fertilizer blends.

Compost

Composting livestock manure and other organic matter stabilizes the nutrients by partially decomposing the materials. Nutrients from finished compost are more slowly released than from fresh livestock manure. Compost is considered mature (i.e., finished) when most of the easily decomposed components of the material have been broken down and biological activity has slowed. At this time, the pile returns to ambient temperature, and it does not reheat when mixed or turned. The composting process results in a dark-brown material in which the initial constituents are no longer recognizable and further degradation is not noticeable. The length of time needed to achieve finished compost will vary with many factors and can take anywhere from a couple of weeks to over a year.

Application of unfinished compost could affect plant growth adversely because the compost-making microbes may compete with the crop for nitrogen. Applying compost at

least one week before transplanting or seeding a crop will allow a margin of safety in case the compost is immature. Immature composts made from nitrogen-rich feedstock are also often high in ammonium, which can change to ammonia gas and be toxic to plant growth. High ammonium concentrations are not typically a problem if the compost is field applied, but if compost will be used in a greenhouse mix, it is important that it be low in ammonium.

Vegetable growers can make compost on the farm although most don't have enough raw materials to satisfy their needs. Some bring in additional materials such as manure or municipal yard wastes to compost on-site. Others purchase compost from the increasing number of commercial composters.

Compost as a nutrient source. Finished compost is a dilute fertilizer, typically having an analysis of about (1-1-1 N-P₂O₅-K₂O), but the analysis can vary greatly depending on the types of materials used to make the compost and how

Type of manure	Dry Matter	Total N	NH ₄ -N	Organic N	P ₂ O ₅	K ₂ O
lbs/1,000 gallons						
Dairy, liquid	<5%	12-16	4.9	7.3	4.8	15.1
Dairy, slurry	5%-10%	22.3	7.6	14.7	8.9	22.0
lbs/1,000 gallons						
Dairy, semi-solid	10%-20%	8.5	1.8	6.7	4.1	6.1
Dairy, solid	>20%	5-12	1.4	10.9	8.1	10.0
Beef (paved lot)	29%	14	5	9	9	13
Swine (hoop barn)	40%	26	6	20	15	18
Sheep	25%	23	n/a	n/a	8	20
Poultry, layer	41%	16-37	18	19	55	32
Poultry, broiler	69%	75	15	60	27	33
Horse	20%	12	n/a	n/a	5	9

Adapted from Nutrient Recommendations for Field Crops in Vermont (2018). Dairy manure values are from Vermont samples analyzed by University of Maine, 2012-2016, others are adapted from University of Nebraska-Lincoln NebGuide G 1335 and Penn State Agronomy Guide (2016). Values do not include bedded pack. Manures vary greatly, so obtaining a manure analysis is always best practice. n/a = data not available.

	Cattle ¹ Thin (<5% DM)	cattle Medium (5%-10% DM)	cattle Semi-Solid (>10% DM)	Cattle Solid (>20% DM)	poultry Solid (>20% DM)
Time to incorporation by tillage or rain	% NH₄ - N available to crop				
Immediate	95	95	90	95	95
< 8 hrs	80	70	60	80	90
1 day	70	55	40	60	85
2 days	65	50	30	45	80
3-4 days	65	45	23	35	70
5-7 days	60	40	25	25	60
>7 days, or not incorporated	60	40	20	10	50

¹ Dairy cattle or other livestock. Adapted from Nutrient Recommendations for Field Crops in Vermont (2018).

they were composted. Composts should be analyzed for their available N, total N, P₂O₅, and K₂O content before application to agriculture fields.

Carbon to Nitrogen Ratio. The recommended C:N ratio for finished compost is 15-18:1. The C:N ratio plays a crucial role in the availability of nitrogen in any organic material added to the soil. If the C:N ratio is much above 30:1 microorganisms will immobilize (i.e., consume and make unavailable for plant uptake) soil nitrogen. This soil nitrogen will remain unavailable until the carbonaceous material is consumed by the bacteria.

Material	C:N
Legume hay	15-19:1
Non-legume hay	24-41:1
Corn stalks	42:1
Oat straw	70:1
Rye straw	82:1
Cow manure	18:1
Finished compost	17-20:1
Agricultural soils	8-14:1
Hardwood sawdust	500:1

Nitrogen. The majority of the nitrogen in finished compost (usually over 90%) has been incorporated into organic compounds that are resistant to decomposition. Rough estimates are that only 10%-30% of the nitrogen in these organic compounds will become available in the first season following application. Some of the remaining nitrogen will become available in subsequent years and at much slower rates than in the first year. Repeated annual applications of compost at high rates above 400 pounds of nitrogen per acre can result in excessive amounts of nitrate in the soil.

Phosphorus. There is not much research information published about the availability of phosphorus from compost. The few papers published show that composts made primarily from manures supply phosphorus over the growing season at 70%-100% of the availability of triple superphosphate fertilizer. The amount of organic amendments that can be added without building up excessive phosphorus depends primarily on: 1) the existing soil test P level of the field; and 2) the P₂O₅ content of the amendment. Table 9 shows the effect of both soil test P categories and the P₂O₅ concentration of an organic amendment on the suggested maximum amount of material to apply. If these rates of amendments are applied every year,

analyze the soil for extractable P annually to ensure that soil test P has not risen to excessive levels. Additional compost applications to soil that tests *optimum* for P could increase P to *above optimum* levels. If a soil test shows an above optimum P level, avoid compost applications until P returns to the optimum range.

Potassium. Potassium in finished compost is much more available for plant uptake than nitrogen because potassium is not incorporated into organic matter. However, some of the potassium can be leached from the compost because it is water soluble. In one study, potassium levels were reduced by 25% when finished compost was left uncovered in the open over a winter.

Soluble Salts. In general, soluble salts are not a concern from additions of composts to field soil. However, soluble salts can be a serious problem when using compost in greenhouse mixes. Incorporation of 40 tons per acre of compost in the top 6 inches of field soil would be a ratio of 50 parts soil to one part of compost. Compost used in the preparation of greenhouse media will make up a much greater percentage of the whole mix and therefore will have a greater influence on all aspects of fertility, including soluble salts. It is important to have composts tested for salt levels. Electrical conductivity (EC) is a measure of salt level, and compost used in greenhouse mixes should have EC < 1 mmhos/cm.

Compost and pH. The pH of finished compost is usually slightly alkaline. In general, composts will not raise soil pH to undesirably alkaline levels because of the low total alkalinity of composts. However, caution should be taken if the compost has been "stabilized" with the addition of lime (thus increasing the total alkalinity) or with heavy applications to certain crops such as potatoes, for which the soil pH should be about 5.2. Heavy applications can cause increases in soil pH that might last for a growing season.

Heavy Metals and Trace Elements. The danger of heavy metals in some composts has received much attention. At one time, some heavy metals in some composts were high enough to be toxic to plants (copper, nickel, zinc) or of concern to human health (cadmium). There have been documented cases where elements such as boron have been raised to toxic levels with repeated applications of compost. These composts with high metals or boron were made from materials with high concentrations of these elements. Governmental regulations control the materials that may be used in composts for applications to farmland. None of these toxicity problems are likely to occur with compost that has been made from farm manures or crop residues or with the commercially available composts of today.

Compost/organic amendment P ₂ O ₅ content	Soil test phosphorus (P) Category				
	Very Low/Low		Optimum		Above Optimum
	P ₂ O ₅ (lb/acre)	Compost (tons/acre)	P ₂ O ₅ (lb/acre)	Compost (tons/acre)	
% P ₂ O ₅ (dry wt.)					
Low (0.1-0.5%) ¹	330	120	82	30	No application
Medium (0.5-1.5%)	330	30	55	5	No application
High (1.5-3.0%)	330	15	No application	No application	

¹ Assumes moisture content of the compost or organic amendment of 45%.
² Average rates used to calculate amounts of P₂O₅ applied for various rates of compost applications.

Herbicide Residues in Compost. There are broadleaf herbicides registered for use on turfgrass, pastures, and hay crops that retain activity in the manure of animals that have fed upon them, as well as through the composting process of crop residues from areas treated with these herbicides. There have been many cases where vegetable growers have unknowingly purchased organic amendments such as manure and composts that are contaminated with herbicides and have damaged vegetable crops. If you purchase organic amendments, you should be aware of this possibility and get assurance that herbicides are not present in the manures and composts that you purchase.

Have Compost Analyzed. No compost should be applied to field soil or used in greenhouse mixes without testing for nutrient content. If the compost will be used in greenhouse mixes, it should also be tested for maturity. Some soil test labs will test compost. Check to be sure the lab analyzes compost before submitting samples, and make sure to have it tested as a compost sample, not as field soil.

Take Soil Test After Applying Compost. A good way to evaluate the effect of compost on the fertility of a soil is to obtain a soil test after applying compost. It is best to wait six to eight weeks after application before testing the soil to allow the compost and soil to equilibrate. The soil test can measure available plant nutrients, soil pH, organic matter, and heavy metal content of the soil.

Additional Nutrient Amendments

There are many different types of commercially available soil amendments and plant nutrient sources on the market today. While some products contain detectable quantities of nutrients that become available to plants in the near term, other products may instead increase availability of existing plant nutrients in the soil. Many have not been well tested in controlled studies. There are many categories of such products available for purchase. Some, but not all, have been approved for organic production.

Organic Residuals

Organic by-products of industrial processes fall into this category. Note that the use of the word “organic” in this case refers to nature of the material itself, e.g. derived from biological sources. It does not necessarily indicate acceptability for certified organic production. Such materials included in this category are: processed slaughterhouse wastes, leather processing waste, biosolids, papermill sludge, and composts. In general, as these products decompose, plant nutrients are released. Many are sold with the nutrient analysis content listed, which is generally very low on a “percent-by-weight” basis. The greater benefits are usually for soil conditioning, and in some cases, liming activity. Not all of these products are acceptable for certified organic production, and acceptability for use in food production should be verified.

Foliar amendments

Foliar feeding has become a more common practice among some vegetable farmers. Many products are now available on the market, for use in both conventional and certified organic production. Foliar feeding is not recommended as a major source of nutrients for a growing crop, but it can be used for supplemental feeding under certain circumstances.

Such circumstances include: 1) when soils are cold and N and P mineralization rates are low; 2) at the onset of nutrient deficiency symptoms in rapidly growing plants (verified by properly conducted leaf tissue testing); and 3) during periods of high nutrient demand, especially fruiting. Even so, nutrient deficiencies often result from indirect causes, such as water issues, soil compaction, pH, root diseases or even macronutrient (N, P or K) deficiencies that can be limiting micronutrient uptake or availability. Addressing these issues is likely a more long-term, as well as time and cost effective way to ensure crop micronutrient needs are met.

New England soils are glacial in origin and are considered “young.” For this reason, our soils are not typically lacking in micronutrients. In soils with pH greater than 7, metal cations become less available to plant roots, and plants may show signs of deficiency. Most soils in New England are acidic, requiring periodic lime applications. Where soils are alkaline, the best way to correct deficiencies of Zn, Mn, Fe and Cu may be to apply foliar sprays of these nutrients in chelated form. Certified organic growers should ensure that they are using forms allowed under organic certification. In some cases, it may be necessary to lower soil pH using products such as elemental sulfur, aluminum sulfate or ammonium sulfate.

Plant Biostimulants, Biofertilizers, Microbial Biostimulants, Microbe-containing Bio-products

A biostimulant is a substance or microorganism (or mixture of one or more) applied with the intent of enhancing a crop’s nutrient efficiency, abiotic stress tolerance and/or quality traits, regardless of the material’s nutrient content. There are now hundreds of commercially available products that fall into these categories. This does not include products labeled for pest control purposes, however, which fall under strict EPA guidelines mandating EPA registration.

One category of these products is familiar to most: various strains of species of *Rhizobium* inoculants for legumes. Research has consistently shown the benefit of legume inoculation to realize full nitrogen fixation potential of legumes, provided that the plant and bacterial species are properly matched.

There has been a proliferation of mycorrhizal fungus inoculant products. These fungi are symbiotic with many crop plants (excluding brassicas and a few others) and extensive research has shown their beneficial effects on plant nutrition, growth, and stress reduction in field, nursery pot and greenhouse conditions. The fungi live inside plant roots, where they obtain a carbohydrate energy source from plants. In turn, the fungal mycelia transfer water and mineral nutrients to plants, which they can extract from the soil volume more efficiently. In this way, the fungi “extend” the rhizosphere that surrounds plant roots. Unfortunately, real-world test results of these products are not readily available. It is unknown at this time whether inoculation has short or long-term economic impact in annual vegetable production.

There are numerous other soil microbial inoculant mixtures available from commercial suppliers. Peer-reviewed research with many of these organisms has shown some positive potential. They are intended to influence crop plants’ rhizosphere, promoting potential availability of mineral nutrients already present in the soil, sometimes by stimulating

plant responses to stresses or diseases. They do not, however, directly supply nutrient elements to plants. There may well be a promising future for microbial inoculants, particularly if it means reduced fertilizer input, but product effectiveness has not been well documented at this stage.

Compost Tea

The legal definition of compost tea from the National Organic Program is “A water extract of compost produced to transfer microbial biomass, fine particulate organic matter, and soluble chemical components into an aqueous phase, intending to maintain or increase the living, beneficial microorganisms extracted from the compost.” Microbial species content is highly variable, depending on the source of compost and the “brewing” conditions. Compost teas have a very low analysis of plant nutrients. Although they are widely produced and used on farms of various scales, research evidence of their efficacy is inconsistent at best. Benefits of using commercial microbial inoculants are variable, and using compost tea is even less dependable despite its widespread popularity. If you do plan to use compost tea, care must be taken to avoid cultivating bacteria harmful to human health (e.g., start with finished compost, use potable water, and avoid using additives like molasses).

Humates, humic acids, humic substances

These materials are made of very large and complex molecules. Most commercial products are extracted from peat or soft brown coal deposits of lignite. Extraction processes and treatments vary widely, so it is difficult to make comparisons between various products on the market. Humic materials contain only small amounts of plant nutrients, thus are not considered fertilizers. Their usage has been promoted by some to provide physical, chemical, and biological benefits to soils. These materials have been studied for over 50 years, mainly in controlled settings, with mixed results from laboratory and greenhouse studies—some resoundingly positive reports, many neutral, and a few detrimental. Under field conditions there are few documented positive effects from their usage. Naturally occurring compounds in soil organic matter effectively perform the same functions, such as chelation of micronutrient metals, and possibly plant hormonal effects. Nevertheless, there are many commercial products available, and little consistency among them.

Seaweed extract products

Seaweeds have been applied to agricultural land for at least a few thousand years and until recently, their primary benefit was considered to be similar to that of other organic amendments, releasing nutrients through decomposition. It was discovered over 50 years ago that seaweed nutrient content was too low to directly boost soil test nutrient levels and that other growth stimulating mechanisms must be involved. Seaweed has been proposed to have several different effects on the root zone environment and on plants themselves.

Though seaweed extracts are used in crop production in large quantities world-wide, there is surprisingly little published research on their use and effectiveness in field settings. One of the more common claims is alleviation of the effects of environmental stresses, such as temperature and moisture extremes. Therefore, when used during typical

conditions, their effects are hard to detect. Subtle effects are difficult to measure in the field, alongside many other possible factors.

GUIDELINES FOR ORGANIC FERTILITY MANAGEMENT

A strong organic fertility program considers the interrelated factors of a given soil's biological, physical and chemical characteristics to optimize and sustain crop production. Organic production emphasizes the use of amendments to build soil fertility and soil organic matter content, which influences the physical and biological quality of soil.

Soil amendments used in organic cropping systems are typically complex, whole nutrient source (e.g., compost, manure, seed meals and rock powders). Because most of these provide many of the plant nutrients, it is challenging to maintain nutrient balance over time. As a result, excessive levels of certain nutrients (especially phosphorus) may build up. Soil testing allows for monitoring trends over time, enabling growers to adapt their nutrient management strategies to optimize yield and minimize environmental impact. If a nutrient is rapidly accumulating, then adjustments should be made in the fertility program to provide only those nutrients needed.

In general, the goal should be to maintain nutrient elements within the *optimum* range as reported on the soil test. When nutrient levels are within this range, the needs of most crops will be met. If levels are *below optimum* (very low or low), most crops will benefit by increasing levels to *optimum*. However, if levels are *above optimum*, there will be no additional benefit, and excess levels may reduce crop yield or quality, attract pests, and may cause environmental harm. This frequently occurs on organically managed fields where soil testing was not used to monitor fertility levels and large amounts of manure or compost have been applied over the years. When a nutrient is above optimum it should not be included in any amendments until the excess is taken up by crops. See Soil Testing, page 10.

Organic matter management is an essential part of organic agriculture. Generous additions of organic materials, such as animal or green manures, are needed to feed soil microbes. Organic matter also is essential because the by-products of decomposing organic amendments bind soil particles to improve soil structure, which is key to good drainage and soil aeration. In addition, organic matter is the storehouse of nutrients in the soil. Many nutrients, especially N, P, S, Cu, and Zn, are mineralized and released when organic matter decomposes.

Decaying soil organic matter releases nutrients unevenly during the growing season. The rate of release is dependent on the type of organic material. For example, compost, which primarily decomposes in the compost pile, is slower to release nutrients than manures (see Tables 10 and 10a). The rate of release during the season is also dependent on soil moisture and temperature that impacts microbial activity. Cool, wet or dry soils typically slow decomposition and mineralization. In the late spring after the soil warms there is usually a flush of nutrients, and the rate of release commonly declines after that. When the release of nutrients is low, fertilizing with soluble forms of nutrients may benefit crops.

This is why some available phosphorus and nitrogen should be banded, or placed near the roots of crops early in the growing season. For example, use bone meal and a seed meal (like peanut or soybean) to provide some available P and N, respectively, or use a commercial organic fertilizer blend. See Tables 10 and 10a for the nutrient content of several common fertility amendments approved for organic production.

Nitrogen Anywhere from 10%-90% of the N contained in compost, manure, and plant and animal byproducts may become available to plants during the season following incorporation (Tables 7, 7a). On average there is a release of about 20 lb N per acre for each 1% soil organic matter. These releases of N vary with drainage and other soil conditions, and may not be well timed to crop needs, especially for early, short season crops. Many annual crops

Table 10: Typical Nutrient Values for Common Fertilizers Approved for Organic Production.

	Total N (%) ¹	C/N ratio	Fraction of organic N made available first season ²	P ₂ O ₅ (%)	K ₂ O (%)	Relative Availability ³
Plant residues						
Alfalfa meal	2-3	15-20	0.25-0.4	0.5	2.5	slow/med
Cottonseed meal	6	5	0.6-0.8	2	2	med/fast
Soybean meal	7	5	0.6-0.8	2	2	med/fast
Peanut meal	8	11	0.6-0.8	1		slow/med
Animal products						
Dried blood	12	3	0.6-0.75	1	0.5	fast
Bone meal (steamed)	3	4	0.25-0.35	15	0	med
Bone char	0	-	-	15	0	med
Feather meal	13	4	0.6-0.8	0	0	med/fast
Fish emulsion	4	3	0.7- 0.9	2	0	fast
Fish meal	9-10	4	0.6-0.8	7	0	med/fast
Manure						
Dairy, with bedding	1	18	0.3-0.5	0.5	1	med
Horse, with bedding	0.5	25	0.2-0.4	0.2	0.5	med
Broiler litter	3-4	15	0.4-0.6	3	3	med/fast
Layer manure	1-2	10	0.4-0.6	3	1.5	med/fast
Bat guano	6	2	0.6-0.8	9	2	fast
Compost (mature)						
Manure	1.5-2	15-25	0.1-0.15	2	1	very slow
Yard waste	0.5-1	20-25	0.1-0.2	1	1	slow

Table 10a: Typical nutrient values for common mineral materials approved for organic production.

	Total N (%)	P ₂ O ₅ (%)	K ₂ O (%)	Ca (%)	Mg (%)	Relative Availability ³
Potassium sulfate	0	0	50	0	0	fast
Sol-Po-Mag	0	0	21	0	11	fast
Epsom salts	0	0	0	0	10	fast
Wood ash	0	1	10	25	2	med/fast
Gypsum	0	0	0	19-23	0	med
Dolomitic lime	0	0	0	20-30	10-12	med
Calcitic lime	0	0	0	40	<5	med
Colloidal rock phosphate	0	25 ⁴	0	20	0	slow
Rock phosphate	0	20-32 ⁴	0	25	0	very slow
Granite dust	0	0	3-5 ⁴	2	1	very slow
Greensand	0	1 ⁴	4-9 ⁴	0	0	very slow

¹ Nutrient concentration of organic materials is inherently variable. Estimated values are provided for reference only. It is best to have materials tested in order to determine appropriate application rates.

² Compost, bat guano, poultry litter, and animal manures also contain varying quantities of NH₄, which is immediately plant available; however, NH₄ is subject to volatilization losses if material is not immediately incorporated.

³ Relative nutrient availability of lime and rock powders varies with origin of material, soil pH, and for rock powders, depends largely on fineness of grind.

⁴ These values represent total K₂O and P₂O₅. Available K₂O and P₂O₅ from these materials will be much lower.

need N most intensely about three to four weeks after transplanting, or just before the period of maximum growth. Therefore, sidedressing, or spreading a rapidly available source of N along the crop row so it will release nutrients at this time is most efficient. Examples of appropriate materials include feather meal, blood meal, seed meals, and dehydrated poultry litter. These materials are relatively expensive, so it is advisable to use them on high value crops. A PSNT collected at the right time can help estimate the most appropriate rate. See Nitrogen and Nitrogen Management under Plant Nutrients, page 1.

Calcium is typically supplied in sufficient quantities by lime applied to manage soil acidity. When liming is not required and soil Ca tests below optimum, the best alternative source of Ca for organic producers is gypsum.

Magnesium is best applied as dolomitic lime, but when liming is not required, other Mg sources are Sul-Po-Mag or Epsom salts. Sul-Po-Mag is the better choice if potassium is also required. However, Epsom salts can be applied as a foliar spray to temporarily alleviate Mg deficiency. Dissolve 15 lb per 100 gal water and spray at weekly intervals.

Limestone is a widely used rock powder. It raises the soil pH and provides calcium (Ca) and varying amounts of magnesium (Mg). The appropriate rate of lime stone should be determined by soil testing and adjusted based on the Equivalent Neutralizing Value of the material. The selection of dolomitic or calcitic lime should be based on soil test levels of Ca and Mg. When Mg tests below optimum, dolomitic, or high-Mg limestone, should be used for liming. If Mg is optimum, a calcitic, or low-Mg lime may be used.

Phosphorus is low in many New England soils, and can limit crop growth, especially early in the season. Maintain a pH of 6-7 with limestone to maximize P_2O_5 availability. Compost and manures are an excellent source of readily available P_2O_5 . Compost and manures tend to contain less P_2O_5 than N or K_2O , but repeated applications of moderate rates will raise P levels substantially. Repeated use of these materials may result in excessive soil levels. Nutrient levels should be monitored with regular soil tests. If P levels are much above optimum, no amendments containing P should be applied (including compost), to reduce P levels over time.

Potassium is best applied at or near planting time because it is soluble and easily leached. Sul-Po-Mag is the K fertilizer of choice when Mg is also needed. Potassium sulfate from natural sources is a better choice when K is needed but Mg is not. Potassium is very slowly available (several years) from granite dust and greensand, which may be applied at 3-5 tons to the acre to build up K reserves. Wood ashes contain soluble K, but must be used with caution because they can raise pH rapidly and can be caustic. The liming effect of ashes can be variable, though is often estimated as roughly half that of limestone. If large amounts are to be used, best practice is to have the material analyzed for both K content and Calcium Carbonate Equivalence (i.e., liming potential).

Micronutrients are generally sufficiently supplied to plants by regular additions of organic amendments. Wood ash is another excellent source of micronutrients. Some seaweed extracts may also supply micronutrients. In soils low in boron (B), remedial applications are widely recommended for crops that readily suffer from B deficiency, such as

brassica crops. In this case, 1-2 lb B per acre should be applied to the soil. It is difficult to apply such a small amount uniformly, but boron can be ordered as part of a custom fertilizer blend. Most boron products are soluble and can be sprayed evenly over the soil. Several forms of B are OMRI listed, including Solubor, Fertibor and Biomin Boron. It is advisable to monitor B levels with soil tests and tissue tests (for perennial fruits). Excess levels of B are toxic to plants, and some crops, such as beans and peas, are quite sensitive to high boron levels (see Table 3, page 5).

REDUCED TILLAGE

The excessive tillage that occurs on most vegetable farms (plowing, harrowing, cultipacking, bed formation, cultivating) has many unintended consequences for soils and the environment. Some of the problems associated with excessive tillage include loss of organic matter and beneficial soil organisms; increased soil erosion and pesticide runoff; reduced soil fertility; loss of soil structure and porosity; compaction, surface crusting, formation of plow pans, reduced root growth, poor drainage, and reduced water-holding capacity. Results from a survey of 55 vegetable farms in Connecticut found that almost 90% of conventionally tilled vegetable farms had plow pans, compared with 33% for reduced-till operations, while the latter group had almost twice as much organic matter in their soils.

Tillage is also expensive and consumes a lot of energy. Reduced-tillage systems can often reduce fuel usage and reduce field preparation time by over 66% when compared with conventional tillage systems. These systems can provide equal or better yields than conventional tillage and may provide many other benefits as well.

Reducing the amount of tillage that takes place can help reverse the problems associated with excess tillage and begin to restore the health of a soil. A simple way to reduce tillage on your farm includes swapping from moldboard plows, disk-harrows and rototillers to using less impactful implements like chisel plows, subsoilers, s-tine cultivators and spaders. You may also work towards implementing minimum tillage systems such as strip-till, zone-till, ridge-till, no-till or permanent-bed systems. Most reduced-till systems are used in conjunction with cover crops or organic mulches to protect the soil surface at all times, help increase organic matter over time, or to help control weeds. Other examples of ways to reduce tillage include:

1. Using chisel plow shanks, subsoilers or zone-tillers to loosen soil before preparing raised-beds instead of a plow and harrow;
2. Planting summer cover crops, such as buckwheat, after an early cash crop as a substitute for repeated harrowing to control weeds;
3. Mowing crop residues instead of disking;
4. Planting tillage radishes or other deep-rooted cover crops to help prevent plow pans from reforming;
5. Using a no-till drill to plant cover crops, instead of a harrow to assure good seed-to-soil contact for emergence.

Deep zone-tillage, also known as vertical-tillage, is one of the more promising and versatile methods of reduced tillage for

vegetables in our climate and can help vegetable farmers reverse the ill effects of years of excessive tillage on their soils. Deep zone-tillage is similar to no-till in that it relies on the residue of a cover crop to protect the soil surface and help improve soil health over time. However, no-till relies on a heavy blanket of plant residue in the planting row to protect the soil, and inadvertently delays crop growth by keeping soils in the root zone cool in Northern climates. Deep zone-tillage addresses this issue by incorporating a 5"-12" wide tilled strip to simultaneously break up plow pans, prepare seedbeds and warm the soil. Planting and fertilizing can often be done in the same pass, further reducing fuel, machine hours, labor costs, fertilizer rates, and soil compaction. Soil drainage can be improved immediately and continues to improve each year. The same herbicides, or some of the same cultural practices, are used to control annual weeds.

Implements used for deep zone-tillage usually consist of a lead coulter to cut through the killed-cover crop residue, followed by a deep shank or subsoiler to break up the plow pan, and finally a pair of fluted coulters and a rolling basket to prepare a narrow seedbed and help break up soil clods. The deep shanks are mounted onto a hinged frame, which allows the shanks to rise out of the ground when they encounter large rocks or ledge, while spring resets push the shanks back down into position after passing over the obstacle. Crop roots grow deep through the slit made by the shank rather than just spreading out in the top few inches of soil above the plow pan. Additional coulters or (finger-like) residue managers are mounted on the planter in front of the planting shoes to remove excess cover crop residue and stones to provide finished seedbeds.

The soil surface between the crop rows retains the heavy surface residue from the dead cover crop. The 5"-12" wide tilled strip warms faster than residue-covered soils and, if installed across a slope, does not allow water to build up enough speed to erode a slope. Roots and surface residue from the cover crop in the untilled area between crop rows do not break down as fast as when the soil is tilled/aerated, so organic matter tends to increase over time. With the return of organic matter, comes the return of beneficial soil organisms, better soil structure, better water infiltration and holding capacity, and a healthier, more productive soil.

There are challenges to successful zone-tillage management. Killing cover crops and weed control can be problematic, especially with organic systems that do not allow herbicide use. Plant establishment can also be negatively affected by the presence of cover crop residues. Growers will need to be innovative to overcome these challenges. Organic growers may try planting perennial rye or turf grass in the fall, and using a modified rototiller with the outside tines removed, to prepare narrow strips or seedbeds at the desired row spacing in the spring. A subsoiler could be used to rip through the plow pan under the prepared strip to improve drainage. The living grass mulch between the crop rows can be controlled by mowing, while weeds within the row could be controlled by mulching, flaming or hoeing, or by planting competitive crops, such as summer squash. At the end of the season, simply seed the strip back to turf. The next season, move the strips mid-way between the previously prepared rows and switch crops to complete your crop rotation.

There are other options to avoid using herbicides. Before early-planted spring crops, use fall-planted oats or a blend of cover crops that winter-kill, such as oats and tillage radish, before zone-tilling and planting. Cultivation can then be used for weed control over the relatively broken down cover crop residue. For summer vegetable plantings, use winter rye, but wait until it sheds pollen in June to crush it with a roller crimper, or cut and bail or windrow it to help suppress weeds between rows. Organic farmers who have worked most of the weed seed bank out of the top few inches of their soil through a combination of winter/summer cover crops, mulches, summer fallow periods and timely cultivations, may find it easier to adapt to zone-tillage than those fighting high levels of weed seeds in their soils. Note that specialized cultivation equipment will be needed to manage in-row weeds. The heavy residue or living mulch between rows will make mid-season cultivation of those areas difficult. Be sure to try this practice on small areas with low weed pressure. Small farms with equipment of insufficient size to pull a zone-tiller, might try lighter weight equipment to break through a plow pan and produce a seedbed, such as a Yeomans Plow, which can be pulled with 16-18 horsepower.

Strip-tillage, sometimes referred to as shallow zone-tillage, is similar to deep zone-tillage without the subsoiling shank to break up the plow pan. The implement has two or three closely spaced coulters and a rolling basket to prepare and smooth a narrow seedbed through the surface residue. Because the implement lacks a deep shank, this system does not have the ability to improve drainage immediately, and it may take several years for the soil health attributes and drainage to improve. However, on farms without a plow pan this system can provide most of the benefits of deep zone-tillage and uses less fuel.

Strips for cash crops can vary in width. To make wider strips in winter rye and vetch for late-planted vegetables, use a spader to prepare planting strips early in the spring when the rye just begins to grow, leaving equally wide strips of the cover crop to mature. A cultipacker or some other finish tool may be needed to smooth the seedbed for small seeded crops. Plant or transplant the cash crop in the prepared beds while the cover crop continues to grow between the beds. To kill the cover crop, cut it when the rye is shedding pollen or when the vetch begins to flower, and spread the straw residue over the prepared bed as a mulch to help suppress weeds around the cash crop. It is best to cultivate the beds once before cutting and spreading the residue from the adjacent cover crops. Supplement the rye/vetch mulch with straw from a nearby field of rye.

For early season vegetables, use a two-year system with spring-planted oats and field peas. During the first summer, after the cover crop forms seeds, mow it to get a thicker stand late in the season. After the cover crop winter-kills, use a spader to make planting beds for vegetables and use a straw mulch between beds or cultivate. A similar process can be done with medium red clover sown between or under a cash crop the first year. When the cash crop is harvested and mowed off in late summer or fall, the clover will fill in to make a solid stand by spring. A spader can then be used to make seedbeds for the new cash crop in the clover stand.

No-Till planters have double-disk openers and closing wheels to create and close the seed furrow in unworked soil, through

a thick cover crop residue. These planters rely on down-pressure springs and/or extra weight to assure that the seed furrow can be created, especially in a dry or compacted soil. If the accumulated crop residue is too thick or unevenly distributed the planters may also have residue managers to move some of the debris before planting. No-till planting can be used for late-planted vegetables in New England, after the soil has warmed under the cover crop residue. It works well for pumpkins and winter squash or summer plantings of sweet corn or other vegetables. When transitioning from conventional to no-till, yields have been known to decline slightly for a few years before recovering as the soil characteristics improve.

Ridge tillage is a reduced tillage system where the crop is grown on top of permanent ridges. This system works well for fields that are often too wet to work in the spring. To initially construct ridges, start in the fall with a tilled field, and broadcast a cover crop that will winter-kill, like field peas and oats. Immediately construct the ridges and roll them to flatten the tops. In the spring, use a flail mower to chop the dead cover crop residue followed by wavy coulters or a rotary hoe to loosen the top inch of soil. This scrapes away the old crop residue and flattens the top of the ridge in order to plant the new crop. The ridge is then restored to full height during the final cultivation. Usually two cultivations are required to help control weeds, loosen the soil and re-construct the ridges. Straw can also be used between ridges to suppress weeds. The ridges can be replanted for many seasons before they need to be reconstructed. As with many reduced-till systems, specialized equipment is required for planting, cultivating and possibly harvesting. Ridge tillage helps conserve moisture, lower inputs, and provide a warmer and dryer soil environment for seeds.

Permanent bed systems help limit soil compaction and maintain soil structure. Equipment and foot traffic is limited to paths or tracks between the beds. Some permanent beds are raised structures while others are not. There are many different ways to construct permanent beds. One simple method is to use a spader to till the soil and provide a rotation between cover crops and cash crops to provide organic matter, nutrients, weed suppression and a great soil environment for healthy crops. Mulch is often used with permanent raised beds to add organic matter and suppress weeds.

For example, you can use a perennial sod cover crop for wheel tracks to avoid compaction on the beds and to increase habitat for beneficial insects. Properly prepared weed-free compost can be used to fertilize and simultaneously mulch the beds for weeds. Organic growers have found that constructing raised-beds, and then using tarps or a thick layer of weed-free compost as a mulch, reduces weed seeds over time, and the same beds can be used for years, with straw mulch to control weeds between beds.

CROP ROTATION

Crop rotation is defined as a deliberate planting sequence over multiple growing seasons in which certain types of cash crops follow others. Such schemes are formulated for a variety of plant and soil health reasons. However, on farms

where soil health is a key focus of management, cover cropping and crop rotation schemes have overlapping functions and the two practices are intermingled. Here, the benefits and challenges of crop rotation are described.

A key principle of Integrated Pest Management (IPM) is the avoidance of pests and diseases using a variety of available means, giving preference to low impact prevention strategies over curative ones. One particularly effective and cost-free method involves moving crops of particular susceptibility from one location to another, season after season. This acts to break up the life cycles of some pests and diseases, as long as the next crop is an unsuitable host for them. Likewise for weeds, changing to a different crop may necessitate tillage at the time of a weed species' greatest susceptibility.

A great number of crop pests specialize in feeding on plants of particular families or even genera. A well-known example is the Colorado potato beetle's preference for members of the *Solanum* genus, especially potato and eggplant. For pests that are considered to be generalists, such a strategy does not work. An example of this would be European corn borer, which can be a pest on corn as well as peppers, beans, potatoes, and many more crops, including ornamentals. Plant diseases also follow a similar pattern: *Alternaria solani*, known as early blight on tomatoes, potatoes and eggplant, is a specialist; *Verticillium dahliae* and *Fusarium oxysporum* have wide host ranges and so are difficult to control using a rotation strategy. Nevertheless, rotation is advisable whenever possible. If you have had trouble with an identified pest, check its host range and avoid following with a susceptible crop.

Growing the same crop, season after season, necessitates the repeated use of similar cultural practices, including tillage, cultivation, fertilizer proportions, and timing within the season. Altering that sequence may explain the commonly reported 10%-15% corn yield increase when it is rotated with soybean, rather than continuous corn. In the case of vegetables, beans and peas, which are leguminous, can follow a crop with a heavy nitrogen demand, such as sweet corn, potatoes, and long-season brassicas. Rooting zone also determines where nutrient demand is greatest in the soil profile. Shallow-rooted crops such as salad crops, radishes and other short-season vegetables can be rotated with deeper-rooted parsnips, carrots, tomatoes and Brussels sprouts. Rooting depth also determines tillage depth, which is important to alter from season-to-season in order to avoid creation of a plow pan.

Various crops have different planting patterns in the field and impacts on the soil. Rotation between densely planted and widely-spaced crops changes water and wind movement patterns, helping to reduce erosion risk. The cultivation, hilling and harvesting of potatoes, as an example, all lead to the deterioration of soil health in those fields. A good crop rotation plan would follow potatoes by either a season of cover crop, or a cash crop such as a legume that has minimal impact on soil health.

It is a good exercise to develop a rotation scheme on paper, something that will help you to project your land use several years into the future. There is an excellent workbook for this purpose from SARE (Crop Rotation on Organic Farms: A Planning Manual. Charles I. Mohler and Sue Ellen Johnson,

editors.) Start by making maps of your fields. The USDA NRCS's Web Soil Survey creates maps with many useful data layers including soil type and has tutorials online: (<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>)

Research has shown that cover crops can improve soil qualities in several respects and should also be incorporated into rotation schemes, including those that winter-kill, those that grow well into the spring, and those that fit into summer fallow periods. See the Cover Crops and Green Manures, below.

Your rotation plan has to be tailored to fit your soils, climatic conditions, crop mix, equipment, and marketing plan. Finally, remember that no crop rotation will ever be perfect; there are always trade-offs. Some ideas for rotations that include cover crops and vegetables in New England are listed in Table 11.

COVER CROPS AND GREEN MANURES

Cover crops are grown to protect and/or enrich the soil rather than for short term economic gain. When turned into the soil for fertility, a cover crop may be called a green manure. Cover cropping is an important part of a vegetable crop rotation plan in order to maintain soil health and manage insect, weed, and disease pressure.

Cover crops offer many benefits, but not all at once, nor from one species. Identifying management priorities helps one select the best cover crop to use in a given field. Do you need to protect the soil from intense erosion, alleviate compaction, suppress weeds, build organic matter, and add N or mop-up available nutrients after the growing season? Fast-growing, thick covers are best for erosion control and weed suppression; high biomass covers add the most organic matter; legumes provide N; cold-hardy covers can mop-up nutrients that remain in the soil at the end of the growing season.

Cover crops can be alternated with vegetables in many ways, including: as a winter cover sown in early fall; as a summer cover sown in late May or June; as a spring cover sown as soon as the ground can be worked; as a strip crop in-between rows, beds or blocks of vegetables; or as a long-term fallow in a field taken out of vegetable production for a season or more.

When fitting cover crops into the fall through spring (overwinter) window of your crop rotation, consider the residue amount and if the cover crop will overwinter or winter-kill. Living (overwintered) cover crops with heavy residue (ex. winter rye) are good when planning to plant warm season cash crops in next season. These options work well for no-till or deep zone-tillage systems. Overwintered, low residue crops (ex. winter peas) are good before small seeded late spring crops, and for farms with limited tillage equipment. Winter-killed, high residue crops (ex. sudangrass) work well for providing cover over the winter, yet allowing early spring planting. Winter-killed, low residue crops (ex. forage and oilseed radish or field peas) allow for planting of early season small seeded crops.

To get a strong cover crop stand requires good soil-to-seed contact, uniform seed distribution and seeding depth, and adequate soil moisture and fertility. A weak or inconsistent cover crop stand will not provide many benefits to soil health and may allow for high levels of weed growth within the cover. Recommended seeding rates for a cover crop vary depending on the equipment used and soil conditions. Drilling requires less seed than broadcasting as it enhances soil-to-seed contact, and less seed is recommended for a well-prepared seedbed with optimal moisture and nutrient levels than for sub-optimal conditions. When broadcasting seed, shallowly incorporating (tilling or disking) and rolling or cultipacking greatly increases germination rates.

Before planting a cover crop, make sure that you have the right equipment and the labor to terminate it at the appropriate time.

	Year 1	Year 2	Year 3	Year 4
Alternating Winter Crops/ Vegetable Crops	Plow winter rye plus vetch Late planted (warm season) vegetable crops Oats in the fall	Disk Oats Early planted (cool season) vegetables Winter rye plus vetch in the fall		
One Year in Cash Crops/ One year in Cover Crops	Plow winter rye/vetch Transplanted vegetables Winter rye in the fall	Plow winter rye in late spring Sudangrass or two crops buckwheat Oats plus hairy vetch in the fall	Mow vetch and plow residue Direct seeded vegetables Oats in the fall	Disk oat residue Field peas plus triticale in spring Sudangrass or two crops buckwheat Winter rye/vetch
Two Years in Cash Crops/ Two years in Cover Crops/ Weed Pressure High	Plow rye or disk oats Vegetables Winter rye in the fall	Plow rye late spring Early summer fallow then buckwheat Oats plus field peas in the fall	Disk oats and field pea residue Early summer fallow Sudangrass or japanese millet	Disk sudangrass or japanese millet residue Vegetables Winter rye or oats in the fall
Two Years in Cash Crops/ Two years in Cover Crops/ Weed Pressure Low	Plow rye or disk oat residue Vegetables Oats in fall	Disk oat residue Red clover and oats in spring Mow oats once before oats form heads	Mow red clover 3 or 4 times	Plow red clover Vegetables Winter rye or oats in fall

Letting cover crop biomass get larger than your equipment can handle can make termination and incorporation very difficult. Also, be aware that allowing cover crops to go to seed unintentionally, can lead the some cover crop species becoming a long-term weed problem. Selecting species that you have the equipment and time to manage will avoid these concerns.

Fall-seeded cover crops. These include hardy small grains sown primarily for winter soil protection and nitrogen scavenging, and a few legume cover crops. Small grain options include rye, oats, wheat, spelt, and triticale. Rye is the most cold-tolerant and puts on growth even late into the fall during mild days. It develops a root system that holds soil in place over the winter and in early spring. Oats are not as cold tolerant as rye and not at all winter hardy so they create a winter-killed ground cover that is easily incorporated before planting vegetables the following spring. Wheat, spelt and triticale grow more slowly than rye and are easier to incorporate in the spring. Triticale can be sown earlier to produce more fall growth; spelt grows well on low N soil. Hairy vetch is the most winter-hardy annual legume cover crop. It may be planted alone or in combination with small grains. The later these winter cover crops are planted the smaller the plants will be over the winter, so it is advisable to double or even triple the recommended seeding rate when sowing late in the fall.

Spring-seeded cover crops. These are used to provide early-season soil cover, add organic matter and provide some weed suppression after a winter-killed cover crop or on land left bare over winter. Legumes can be mixed with oats, which serve as a nurse crop to outcompete weeds as the legume gets established. Yellow mustard can be used as a good source of organic matter, with potential for soil-borne disease suppression. It can also suppresses weeds, as can annual ryegrass. These crops are sown as soon as the ground can be worked in early spring.

Early summer-seeded cover crops. These fast-growing crops are used primarily to suppress weeds and add organic matter. Common choices are sudangrass (or sorghum-sudangrass) and buckwheat. Both grow rapidly if there is sufficient warmth, moisture and fertility. Sudangrass is preferable for adding to soil organic matter as it produces a lot of biomass when grown for the entire summer; it also has a deep root system that helps reduce compaction and it can reduce root-knot nematode pressure. If a cover crop is needed for less time, and/or if weed suppression is the main goal, then buckwheat is preferable as it covers the ground earlier than sudangrass, especially in early June, and needs only 35-40 days to produce most of its biomass whereas sudangrass needs 60-70 days.

Late summer-seeded cover crops. These are sown after an early-harvested vegetable crop, a month or two before frequent frosts; mid-August to mid-September in most locations. Winter covers such as rye or oats are an option; when sown early they will produce more fall growth. When sufficient growing time remains in the season several other covers can be used including annual ryegrass, forage radish, hairy vetch, and mustard.

Non-legume cover crops

Annual ryegrass, also called Italian ryegrass, is a turf grass with a dense, shallow root system. Its extensive root system tolerates compacted soil and makes it effective at mopping up available N remaining in the soil after a vegetable crop. It competes well with late summer annual weeds as well as

winter annuals that start in the fall, such as chickweed. This grass will tolerate a wide range of soils but performs best on moderately- to well-drained soils with high fertility. It is well suited to undersowing after last cultivation of a cash crop in order to establish a winter cover prior to harvest. Annual ryegrass is less expensive than perennial ryegrass, and is more likely to winter-kill; however, it may overwinter in milder areas. Perennial ryegrass may winter-kill in harsher zones. Sow from mid-summer to early fall at 5-10 lb/A if drilled, 15-30 lb/A if broadcast.

Buckwheat is a fast-growing summer annual used to protect the soil, add organic matter and suppress weeds for a month or two between spring and fall cash crops. It grows fairly well on slightly acid and low phosphorus soils. It decomposes rapidly, so is easy to incorporate. Mow or incorporate at flowering, prior to seed set so it does not become a weed in subsequent crops. Sow from early to mid-summer at 50-70 lb/A if drilled, 60-90 lb/A if broadcast.

Cereal rye is commonly sown after cash crops are harvested in the fall. It is very hardy, an efficient N scavenger, adapted to a wide range of conditions, and seed is inexpensive. The latest-sown cover crop, it produces a lot of biomass if allowed to grow into late spring. This adds organic matter to the soil but may be difficult to incorporate prior to crop planting. In late spring rye must be carefully managed to prevent excessive growth, and allowed time to break down so it will not interfere with establishment of a subsequent cash crop. Sow at 60-120 lb/A if drilled, 90-160 lb/A if broadcast, from late summer to mid-October in most areas. Incorporate in spring before it gets too large for equipment to handle. Some growers leave narrow strips of rye untilled as windbreaks between blocks of crops in the spring.

Forage radish, oilseed radish, or tillage radish are late summer seeded brassicas that are not winter-hardy. These crops form thick, white taproots that can grow 8-14 inches. Radishes are excellent at breaking up shallow layers of compacted soils; the end of the taproot can penetrate deeper layers of compaction. The roots die over the winter and leave channels so that the soil dries and warms up faster in the spring. Radishes also suppress fall weeds. Some vegetable growers with several brassica cash crops in their rotation do not plant this cover crop to minimize the risk of having another brassica pests and diseases host in the rotation. Plant into a smooth seedbed. Sow 4-10 weeks before fall frost at 5-10 lb/A if drilled in good soil conditions or 10-13 lb/A if broadcast or drilled into sub-optimal condition. Using higher rates leads to overcrowding and weaker growth. Drilling gives a much better stand; broadcasting should be reserved for when the soil is too wet to drill. After seeding, roll the ground to improve seed-to-soil contact. Plant 1/4"-1/2" deep. Forage radish can be planted with 40 lb/A of wheat for spring cover and weed suppression. Higher seeding rates will produce more shading leaves good for weed suppression, while lower seeding rates will produce deeper tap roots, which help break up compaction.

Japanese millet is an annual grass that grows about 4' tall and can provide good weed suppression. It is about the stature of buckwheat but has a longer lifespan so it can keep the ground covered from early summer through fall without mowing if sown heavily. Sow at 20-25 lb/A if drilled, 30-40 lb/A if broadcast. It performs poorly on sandy soils without supplemental fertilization.

Mustard can be used as a fall-planted cover crop that winter-kills. It adds organic matter, and suppresses weeds in the following crop. Soil-borne diseases are suppressed by glucosinolates in mustard and other brassica crops, but results may vary from year to year and in different locations. Different species and varieties contain different amounts of bioactive chemicals. To increase the benefits of biofumigation with mustards, the cover crop should be flail mowed at peak of bloom and then incorporated immediately before a rain event. Plan to either roll the soil and/or cover the area with a tarp to trap in the gases from the glucosinolates. When planting, prepare a firm, weed-free seedbed with adequate levels of available N to assure a good stand. Sow any time the soil temperature is above 40°F and the field is available for 5-7 weeks at 5-12 lb/A if drilled and 10-15 lb/A if broadcast. Roll the ground to improve seed-to-soil contact but do not break up soil aggregates. In the spring, yellow mustard can also be frost-seeded or sown as soon as the ground can be worked. Do not let mustards go to seed. Mustards attract flea beetles and diamond-back moths, but the risk is lowest in the fall. They can also host brassica crop diseases such as clubroot.

Oats are often used as a winter cover crop to protect the soil without requiring intensive management in the spring, because they are frost-killed. Shallow incorporation of residues may still be necessary before crop planting. Enough growth is needed before first frost to adequately protect the soil, so plant from mid-August to mid-Sept in most areas. Sow 80-110 lb/A if drilled, 110-140 lb/A if broadcast. Oat residues left on the soil surface may chemically suppress weed growth and act as a physical barrier. Oats are also a good cover crop to plant any time during the spring or fall to get a quick cover.

Sudangrass and **sorghum-Sudangrass** are fast-growing, warm season crops that require good fertility and moisture to perform well (sorghum-sudangrass is often referred to generically as sudex, although that is a trademarked name). Under such conditions, their tall, prolific growth provides excellent weed suppression. The heavy growth can be difficult to cut and incorporate if left unmanaged. sudangrass growth is easier to manage because the stems are narrower, and it can be sown a little earlier than sorghum-sudangrass. These crops provide abundant root biomass, which is useful for increasing soil organic matter. Mowing when 2'-3 ft. tall encourages root growth. Mowing several times during the season makes it easier to turn in residues later, and it promotes tillering and root growth. These crops may suppress root knot nematodes. Sow once soil has warmed to 60°F, in early summer at 35 lb/A if drilled, 40-50 lb/A if broadcast. Provide adequate moisture and apply N fertilizer if grown on low fertility soils.

Teff is a warm-season grass useful for suppressing weeds if sown at a high plant population. It has a fine plant structure that doesn't leave soil clumpy for the next crop. Although buckwheat and sudangrass are more common choices for early-summer sowing, Teff tolerates dry conditions better. It also requires less maintenance: buckwheat must be controlled when it matures to prevent seed set and sudangrass should be mowed several times. Teff needs minimal mowing and generally does not produce seed, so volunteers are not an issue. Sow in June-July into a very firm seedbed so that the tiny seeds stay near the surface. The crop needs 40-60 lb/A

N, so follow a high-N vegetable or manure application. Sow 5-8 lb/A raw seed or 8-10 lb/A coated seed, or if soil moisture is uneven. Use a Brillion seeder or broadcast followed by roller to press seed into the soil. Plant 1/8"-1/4" deep. Needs frequent light rain or irrigation for rapid uniform emergence.

Legume cover crops

Legume cover crops are often used when "free" nitrogen is desired for a subsequent cash crop with high N demand. Legumes generally require good drainage and adequate P fertility (other than N). Most grow slowly at first so they do not compete well with weeds until established. Drill seed for best stands. Treat legume seed with the proper inoculant to ensure adequate N fixation. Legume cover crops can be sown with a nurse crop such as oats to provide early ground cover and weed suppression during establishment. When legume cover crops with flower buds are mowed, tarnished plant bugs may be driven into adjacent vegetable crops.

Alfalfa requires deep, well-drained soil with a pH near neutral for good growth. It is a long-lived perennial that is probably not worth the expense of establishment in a short-term rotation; it makes more sense if also used for production of forage for 2 or 3 years. Alfalfa fixes large amounts of N that can meet most or all of the needs of a subsequent vegetable crop if allowed to regrow after cutting before it is turned in. Seed in early spring at 6-10 lb/A if combined with a grass nurse crop, otherwise seed at 10-15 lb/A; drill if possible.

Hairy vetch is a winter-hardy, annual legume that is an effective N-fixer. It is useful in vegetable crop rotations as a tool for growing N without taking land out of cash crop production. Once established, it is good at weed suppression and soil conditioning. Generally, this cover crop is seeded in late summer from mid-August to mid-September in most of New England. To gain the most N benefit, it should be allowed to grow until early flowering, about mid-May, before being incorporated the following spring. Sow vetch at 15-20 lb/A if drilled, 25-40 lb/A broadcast. Use vetch/pea type inoculant (not crown vetch type.) Since it is slow to establish, sow vetch with a nurse crop such as rye at 30-40 lb/A or oats at 40-50 lb/A. The grass takes up unused soil N and ensures a good winter ground cover for erosion control. Oats will not overwinter, leaving the vetch alone the following spring, which is easier to turn under and prepare for direct seeding; with rye there is more biomass produced and more soil residue after incorporation which is better suited to transplanting. Hairy vetch can also be seeded in early spring or summer and allowed to grow until the following spring.

Red clover is a short-lived perennial that is somewhat tolerant of acidic or poorly drained soils. It is useful for adding N and organic matter to soils on land that is taken out of production for a season or two. Mammoth red clover produces more biomass for plow-down than medium red clover, but does not regrow as well after mowing. Mammoth red clover will often establish better than medium in dry or acid soils. Seed in early spring or late summer or undersow in early summer into corn, winter squash before it vines, and other crops if soil moisture is plentiful. Sow at 8-10 lb/A if drilled, 10-12 lb/A if broadcast. It can be mixed with sudangrass, sown at half the recommended rate, seeded in early summer.

Sweet Clover is a deep-rooted biennial (except for some annual types) that is adapted to a wide range of soils. It is a good soil-improving crop with a strong taproot that penetrates into subsoil, reducing compaction. Yellow sweet clover is earlier maturing and somewhat less productive than white sweet clover. Sow in early spring or summer at 6-10 lb/A if drilled, 10-20 lb/A if broadcast. Heavy growth is produced in the spring after overwintering. Incorporate in late spring or mid-summer at full flowering.

Soybean or cowpea. These warm-season legumes have potential as cover crops sown in early summer to provide some weed suppression and add high amounts of N to the soil. They are frost and drought sensitive. Though typically grown for their seeds these crops will primarily produce foliage if long-season varieties are used in the Northeast. Forage cultivars may produce more biomass than horticultural varieties. Drill at 30-40 lb/A, 60-100 lb/A if broadcasting; use high rates in sub-optimal conditions, or to improve weed suppression. Avoid damaging seed when handling. Plant 1-2 inches deep, firm up the soil and provide adequate moisture to get good germination. Good soil seed contact and well-drained soils are needed to establish strong stands. Use cowpea/peanut, or soybean type inoculant. These can be grown in mixture with Japanese millet or sudangrass; the latter is taller and may suppress legume growth via shading so used reduced rates.

White clover is a low-growing perennial, tolerant of shade and slightly acid soil. Ladino types are taller than the Dutch or wild types. White clover is a poor competitor with weeds unless mowed. It is suited for use in walkways or alleys. Once established, it provides long-term cover, either alone or with a low-growing turfgrass. It can be used in high traffic areas to minimize soil compaction and improve soil health. White clover tolerates wet conditions. Sow in early spring, frost-seed in March, or seed in early fall, along with a turfgrass, at 3-9 lb/A if drilled, 5-14 lb/A if broadcast.

Crimson clover is a beautiful cover crop that is now able to over-winter in southern New England. It mixes well with annual rye when seeded at 5-15 lbs/A in the early fall. When planted alone, seed at 15-18 lb/A drilled, or 22-30 lb./A broadcast.

Cover crop mixtures. Cover crop mixtures are used to hedge against failure of one component and to get some of the benefits of both. A grass will usually establish quickly, holding soil in place and “nursing” the legume along. By taking up available soil N, the grass promotes N-fixation by the legume. Fertilization with N or the absence of mowing favors growth of grass over legume. Incorporation of several species into a mix can increase the number of benefits, but decrease the amount of each benefit. For example, several grasses and brassicas in a mix will result in less N fixed by legumes in that mix. Quick-growing, competitive grass and brassica species seeding rates should be reduced in mixes, while less competitive legumes should be kept close to monoculture seeding rates.

Interseeding, or under-sowing a cover crop into a standing cash crop is a way get a jump on the fall/winter cover crop season and can help protect soil between rows from erosion and compaction. When interseeding covers, sowing should be delayed enough to minimize competition with the vegetable crop, but early enough so the cover crop can establish well and then withstand the harvest traffic.

Typically, a good time to sow is at last cultivation, before the crop canopy closes. Less competitive crops such as carrots, onions and the like are poorly suited to intercropping. Vigorous vegetables, like winter squash and sweet corn, are better suited to tolerate early-summer interseeding with a cover crop such as ryegrass and/or red clover. Late summer is a better time for interseeding crops like peppers, staked tomatoes, fall crucifers and the like. Traditional winter covers like rye, oats and/or hairy vetch can be used at that time. A good seedbed and timely rainfall or irrigation helps with establishment. Interseeding is not advisable if no irrigation is available or if there are disease problems in the crop that call for the field to be tilled after harvest. Interseeding can lead to increased rodent damage to crops like winter squash.

For more information:

Managing Cover Crops Profitably:

www.sare.org/publications/covercrops/covercrops.pdf

Cover Crops for Vegetable Growers:

www.hort.cornell.edu/bjorkman/lab/covercrops/

IRRIGATION

In most years there are at least some periods of inadequate rainfall. Even a short dry spell can adversely affect crop yield and quality. Irrigation requirements differ somewhat among the various kinds of vegetable crops, but they all benefit from supplemental irrigation when needed. It is critical to manage soil moisture to provide an ample and steady supply of water to crops without overwatering. Table 13 (page 28) lists periods of critical water need by vegetable crops. Special crop requirements will also be discussed in each crop section of this Guide. General irrigation guidelines are presented here.

Contact your local Extension office to determine what information is available in your state. There are also several knowledgeable irrigation equipment suppliers who serve the New England area who can be very helpful. As you begin to plan your irrigation program, keep in mind that it is usually best to look first at the highest value crops you grow as well as the anticipated increases in yield and income with the use of irrigation. When buying equipment and developing water supplies, consider future needs.

General Irrigation Guidelines

Soil Moisture

A soil is saturated when all of its pore spaces are filled with water. This is likely to be the case after a heavy rain or irrigation. After one or two days, when excess water has drained due to gravitational pull, the soil is at field capacity. At this point, the remaining water is attracted strongly enough to soil particles to prevent further drainage, yet it is readily available for uptake by plant roots. Soil water is further depleted by evaporation from the soil surface and transpiration through the plant leaves. The combination of these processes is called evapotranspiration (ET). As soil water is depleted, what remains is held more tightly by soil particles. As this happens it is increasingly difficult for plant roots to extract moisture from the soil. Eventually a point is reached where the remaining water is so tightly held by soil particles that it is unavailable to plants. This is the permanent

wilting point or wilting coefficient. Soil moisture in the range between field capacity and the wilting coefficient is usable by plants and is called available water, although moisture stress will occur as the lower end of this range is reached. It is advisable to begin irrigating vegetables before half the available water has been used. If soil moisture is depleted below this point, plants will be under increasing stress, even though they may not show visible wilt symptoms at first. Moisture stress can greatly reduce yield and cause numerous disorders such as tip burn of leafy crops and blossom-end-rot in tomatoes and other fruits. It may be advisable to begin irrigation when as little as 30% of the available moisture has been used.

To achieve the most benefit from an irrigation system, it is necessary to apply the correct amount of water at the right time. This means replacing the water lost through ET and doing so before plants are under stress. The rate of ET is affected by a number of environmental factors including solar radiation, temperature, wind speed and relative humidity. When it is hot, sunny and windy with low relative humidity, up to 1/3" of water per day can be lost through ET. That is about 2" per week. When it is cool, cloudy and damp with little wind, losses are quite low. As canopy area increases, evaporation from the soil decreases due to shading, but transpiration from the leaves increases and generally ET increases. If weeds are present, their leaf canopy increases ET losses to the detriment of the crop. Evaporation from the soil surface is reduced by the use of organic mulch and nearly eliminated under areas covered with plastic mulch.

Evaporation pans can be used to estimate ET loss. Pans should be filled with a measured amount of water, such as 1", and placed in or next to the field in a sunny spot. The loss of water from an evaporation pan will approximate the amount lost through ET. Although this is not exact, it provides a good indication of the rate of loss when sprinkler irrigation is used. When irrigation occurs, the evaporation pans should be filled with the same amount of water as was applied to the field.

It is important to know the amount of available water that a particular soil can hold. This varies considerably with soil type. For example, a slit or clay loam can hold several times as much available water as a sandy soil (Table 12). Soil organic matter can substantially increase a soil's ability to store available water. It has been estimated that for each percent of soil organic matter, water holding capacity is increased by about 1/2" per foot of soil depth. This depends on the state of decomposition, but it is clear that organic matter has a profound influence on moisture holding capacity. Crops growing on soils with a high available water holding capacity require as much water as those on a soil of low available water holding capacity, because ET is about the same on both types, but the required frequency of irrigation is different. Soils with a high available water holding capacity need less frequent irrigation than those with a low capacity. However, when irrigated less frequently, a greater amount of water should be applied per application. This results in less labor for moving and setting up pipes and sprinklers.

Table 12: Available Water Holding Capacity Based on Soil Texture

Soil Texture	Available Water Holding Capacity (inches of water/foot of soil)
Coarse sand	0.24-0.72
Fine sand	0.48-1.08
Loamy sand	0.72-1.44
Sandy loam	1.32-1.80
Fine sandy loam	1.68-2.16
Loam and silt loam	2.04-2.76
Clay loam and silty clay loam	1.68-2.52
Silty clay and clay	1.56-2.16

Water application rate

The application rate of irrigation should not exceed the infiltration and percolation rates of the soil. Infiltration is the entry of water through the soil surface and percolation is the downward movement of water through the soil. If the application rate exceeds either the infiltration or the percolation rate, water will accumulate on the surface and is subject to run-off and erosion. Soil compaction inhibits both infiltration and percolation and should be minimized. Soil crusting also interferes with infiltration. Soil organic matter reduces soil compaction and crusting. Compaction and crusting can also be minimized by using appropriate tillage practices and restricting traffic over the soil.

Soil tensiometers for measuring soil moisture are available at a cost of \$75 to \$100. They can be purchased through several field equipment suppliers.

Place the porous tube of the tensiometer at the depth you desire moisture measurement. You can calibrate your tensiometer to a particular soil so irrigation is done when the tension on the gauge reads a certain value (a number specific to your soil and the crop you are growing). A maximum value (usually 30-35) would be used for a sandy loam soil and this value may vary with the particular tensiometer purchased. In utilizing tensiometers, be certain you are aware of soil variability within a given field. Three to four tensiometers per field may be needed to adequately account for this variability and, in addition, two depths (commonly 6" and 12") may be necessary to adequately reflect the most critically stressed areas. The 6" unit indicates when soil moisture near the surface is being depleted (begin irrigating) and the 12" one shows when the moisture has moved to the bottom of the root zone (stop irrigation). In a drip irrigation system, a rule of thumb is to place the tensiometer about 6" from the tape at a depth of one-third the entire root zone. During irrigation, the tensiometer indicates when field capacity has been attained at the depth of the porous tube.

When using drip irrigation on plastic-covered raised beds, during rain events where less than one inch of rainfall has fallen, run the drip irrigation system as normal. When greater than one inch of rainfall has occurred, delay the application of water through the drip irrigation system.

Remember, if you wait for crop symptoms (wilting) to decide when to irrigate, the crop will already be damaged.

Critical Periods for Moisture Needs

Vegetable crops should not be under stress at any time. Each crop has its particular periods of critical moisture needs. In many crops (such as sweet corn, beans, and peas), the most critical period is during or just after flowering. These crops have flower development in a much more concentrated period of time. Other crops (tomato, peppers, eggplant, and potato) also have a critical moisture need during fruit or tuber development. Check individual crops for details. (Table 13). Some crops, such as onions, potatoes, pumpkins and winter squash, benefit from dry conditions at the end of the growing season when the crop is curing.

Crop	Critical Period
Asparagus	Brush growth
Snap beans	Pod enlargement
Broccoli, cabbage, cauliflower	Head development
Carrots, radishes, turnip, rutabaga	Root development
Corn	Silking/tasseling and ear development
Cucumbers, squash, melons	Flowering and fruit development
Eggplants, peppers	Flowering and fruit development
Lettuce	Head development
Onions	Bulb development
Potatoes	Tuber set and enlargement
Tomatoes	Early flowering, fruit set and enlargement
Note: These are stages of critical water demand, but vegetable crops should not be subjected to stress at any time during growth.	

Sprinklers

Sprinkler size should be chosen based on the crop, distance between laterals, pumping pressure and volume, and the infiltration and percolation capacities of the soil. Sprinkler placement should be staggered with those on adjacent laterals. This provides a triangular pattern in the field. Sprinklers are designed to operate with patterns that overlap according to the manufacturer's specifications. A triangular arrangement with overlapping patterns provides the most uniform coverage.

Wet conditions are favorable to most diseases. Time the use of sprinklers so that foliage can dry rapidly when irrigation is complete. This is usually in the morning. Irrigating thoroughly to achieve field capacity to a depth of the majority of the root system, and never permitting plant stress, can reduce diseases. Irrigating more often than necessary may encourage disease development by maintaining wet foliage for long periods of time. This can also leach nutrients.

Frost Control

Early- or late-planted vegetables can be subjected to freezing temperatures in spring or fall. Using an overhead sprinkler system that applies about 1/10" of water per hour, during periods when the air temperatures in the crop canopy are below freezing, can reduce or prevent crop losses. Greater or lower applications may be necessary depending on minimum temperature, length of freeze period, and wind speed. Be certain to start irrigating before the temperature reaches freezing and continue irrigating until ice melts. The degree of protection depends on wind speed and other factors. However, protection below 20°F has not been attained.

Trickle or Drip Irrigation

A well designed trickle or drip irrigation system benefits the environment by conserving water and fertilizer and requires little labor to use once it is set up. Water is applied either on the surface, next to the plant, or subsurface, near the root zone. In dry years, fewer weed seeds germinate between rows because there is less water available beyond the plant root zone, although weed roots may grow toward the wet zone, especially when plastic mulch is used. With drip irrigation there is less evaporation than with sprinklers. Evaporation losses from the soil surface are further reduced when drip irrigation is placed under plastic mulch.

It requires some expertise to install and operate a trickle system. Consultation with a knowledgeable professional is wise. A poorly designed system can result in yield variability in the field due to areas of over- or under-watering and clogged lines. Trying to save money by cutting costs on initial equipment purchases will likely be more expensive in the long run. Any or all of these problems can completely offset the potential cost savings from using drip irrigation, but they can be avoided by using good equipment and proper design and installation.

Water source. Organic materials such as plant materials, algae, small living organisms, and inorganic sand, silt, and clay are likely to be found in surface water such as a pond or stream. Well water is likely to have some sand, silt or clay particles, although not as much as most surface supplies. These particles can clog the small diameter emitters in the tape. Filters are used to remove particulate matter as discussed later. Surface water might have contaminants from run-off, which can include pathogens such as *Phytophthora*.

Slope. A slope of 2% or less is the ideal for drip irrigation. Many fields in New England have slopes greater than 2%. A difference of 2.3' in elevation will change water pressure by 1 psi, decreasing as elevation increases and vice versa. The length of lateral lines, the pump size, and pressure regulators are chosen based on the slope. It is best to run the rows horizontally across a slope, but if rows must run up and down, it is best to have the water flow downward through the drip tape. Water should also flow downward in headers. This probably requires that water be pumped to the top of the field so it can flow downward from there. With slopes greater than 5%, pressure-compensating drip tape is needed.

Soil. The soil type determines the soil wetting patterns. Soil wetting patterns in turn influence the depth of the drip tape and the distance between emitters. The duration and frequency of irrigation are also determined by the soil type. Over-watering can move fertilizer away from the root zone. On sandy soils, water goes primarily downward rather than horizontally so emitters should be at relatively close spacing. Spacing between emitters can be greater in heavier soils where there is considerable movement laterally. In sandy soils, irrigate more frequently, but run the water for a lesser amount of time. In heavier soils, irrigate less often, but run the water for a longer duration. In both cases, this should lessen the chance of leaching fertilizers away from the root zone.

Drip tape should apply water uniformly throughout the crop root zone. The emitters should be close enough so that there is uniform wetting of the soil. As discussed above, the spacing of the emitters is affected by soil type. Drip tape should have

a coefficient of manufacturing variation (CV) number that reveals how much variation in uniformity there is from one emitter to the next. A CV of 0.05 is considered excellent and a CV between 0.05 and 0.1 is acceptable. The rate of water delivery is a function of the size and spacing of the emitters and typically ranges from about 2.5-5.0 gallons per minute per 1,000' of tape (0.25-0.5 gpm per 100').

The length of the drip lines is another important consideration. The length is determined by the pump size, the field size(s), and the slope of the land. Any one of these factors will influence wetting uniformity because the emitters will discharge water at different rates if there are changes in pressure along the line. Because of variation in water pressure, tape is rarely laid out longer than a length of 400' on fairly level land and less on slopes. Tape should run across the slope, but if this is not practical, it should run downhill so the pressure loss due to friction is counteracted by the gain as the elevation decreases. If the tape runs up hill, there is a double loss due to friction and increasing elevation.

The choice of tape thickness, measured in mils, is based on how long you want the tape to last and the expected highest water pressure in the lines. The longer the tape is expected to be in the ground, or the higher the pressure in the lines, the thicker the tape should be. Tape thickness is usually between 4 and 10 mil, though thickness of up to 25 mil can be purchased. Tape can be reused for two to three years, but the labor costs of retrieving and cleaning the tape usually make this uneconomical for annual vegetable crops.

Placement of drip tape. The tape should be placed as close to the plant as is practical for the specific crop. This is critical on porous soils, but if necessary, tape can be placed between 6" and 12" from the plants on soils with good lateral water movement. Tape is often laid between double rows of crops such as peppers. The soil will be wetter on the side of the crop where the tape is and most of the roots will be concentrated there. The tape should be placed so that the emitters are pointed upward so that any particulate matter will settle away from the emitters after the water stops flowing.

Tape can be placed on top of the soil or a few inches below the surface. If tape is on the surface, it is easy to observe wetting patterns and to make repairs if needed. The disadvantages are that there is greater evaporation in the initial stages of the crop's growth and the tape is more likely to be damaged by production practices, wind, and animals. As tape is heated by the sun during the day, it expands and takes on a snake-like pattern in the row. This is particularly a problem with higher temperatures under plastic. This can be avoided by burying the tape.

Pumps. For a given area, trickle irrigation uses less water and at a slower rate than a sprinkler system. Therefore smaller pumps can usually be used. The required pump capacity is determined by the flow rate of the tape, total length of tape to be used at a given time and pressure loss due to friction and increases in elevation. Pump size should be determined when designing a system.

Filters. The choice of filter is based on the quality of the water passing through the system and drip application requirements. Typical screen mesh size is 150 mesh (100 micron). The filter should be sized for the longest application

flow rate needed. Water particulates change through the growing season and filter flow rates are affected with dirtier water and more suspended particulates. It is better to design a system larger than is required, compared to smaller.

Screen filter. Screen or mesh filters are inexpensive and easy to install. Mesh filters work well if there are moderate to low contaminants in the water, such as those coming from a well or public water supply. Screen filters have a limited ability to store contaminants. If the water comes from a river or pond, the screens will probably have to be flushed often. This could result in considerable down time and labor.

Mesh screen sizes are between 20 and 200 mesh. The larger the number, the smaller the particle the screen will filter out. The screens are made from stainless steel, nylon, or polyester. Follow the recommendation of the tape manufacturer as to mesh.

Disc filter. A disc filter consists of a series of discs that are stacked on top of each other. The discs have microscopic grooves that radiate out from the center and filter out particles. Equivalent mesh sizes are between 40 and 600 mesh. They require less water for cleaning than do sand filters.

Sand filter. Sand filters are preferred over screen filters if the contaminant load is moderate to heavy. A sand filter can run longer than a screen filter before it needs to be cleaned by back flushing. This results in less down time and labor. The filters can be set up in pairs so that clean water from one filter is used to back flush the other filter. A screen filter can also be used to provide clean water for back flushing a sand filter.

The correct filter size is important. Under-sizing will increase pressure loss and there is considerable down time for cleaning. It is better to be too big than too small. The sand used for trickle irrigation should be of the correct type, made up of crushed, sharp edged silica or granite.

Pipe/Mainlines. Mainlines can be metal pipe, PVC pipe or lay-flat hose. They deliver water from the pump to the submains and laterals. Proper pipe diameter is a function of the pumping rate and distance the water must travel. Larger diameters can move greater volumes and have lower friction losses, but are more expensive than smaller pipes. The longer the pipe and the more elbows or junctions, the more pressure loss due to friction. A qualified designer can help determine the appropriate pipe size for the system.

Care should be taken when laying the pipe to prevent soil or debris from getting into the system and clogging the lines. The lines should be flushed before the tape is connected to remove any dirt that got into the lines during installation.

Back flow preventers or check valves allow water to flow in one direction only. They are used to prevent water from flowing backward into a water source after the system is shut off. This is especially important to prevent injected fertilizer or pesticides from contaminating water supplies. They are required by law for systems with injectors. In some areas they may be required even if no injector is used. Vacuum-relief valves are installed to prevent soil from being sucked into the emitters when a vacuum is created after the system is shut-off.

Pressure regulators maintain the desired pressure as the water flows through the system. They are required to supply the appropriate pressure to tape and may be needed to protect filters and other components. They should be sized according to the rate of water flow. Drip tape typically operates at 12 PSI.

Fertigation

Fertigation is the injection of soluble fertilizer into irrigation water. Nitrogen and potassium are available in liquid or soluble solid form and can be applied through a drip system. Phosphorus, if needed, is usually broadcast at the beginning of the season.

By using a fertilizer injector, trickle irrigation can be used effectively to apply N and sometimes K during the growing season. The need for supplemental N can be determined using the PSNT as it is with other application methods. Samples for the PSNT should be taken from under the plastic, if used. Use a soil sampler to punch a small hole in the plastic and remove a core of soil. Be sure to avoid cutting the irrigation tape when sampling under plastic.

With conventional topdressing or sidedressing, it is common to apply all the N in one or two applications. With trickle irrigation, it is convenient to apply small amounts of N weekly or even daily, which is desirable from a N management standpoint. For example, if you want to apply about 50 lb N per acre, you can inject a little over seven lb N per acre per week for seven weeks, or about one lb per day if you prefer. Small weekly applications provide for more efficient crop use of N than one or two larger applications. Daily application offers little advantage over weekly application, but may be necessary if the injector cannot inject a week's worth of N during the appropriate irrigation run time. To prevent leaching, the irrigation system should not run longer than necessary to effectively wet the root zone of the crop. If there is not enough time to inject all the fertilizer needed for the week in one injection, then smaller, daily injections are preferable. Before injecting fertilizer, the entire system should be filled with water at full operating pressure. When all the fertilizer has been injected, the system should run long enough to flush all fertilizer from the lines. If fertilizer is left in the lines, clogging may occur due to chemical precipitates or growth of bacterial slimes.

Water Problems

There is a potential for certain fertilizer materials to react with chemicals in irrigation water. If the water pH is below 7.0, there is little potential for problems, but at pH 8.0 and above, the risk is high. At levels above 40-50 ppm, calcium and magnesium are likely to react with phosphorus, if present in the fertilizer, causing precipitation of phosphates. If fertilizer containing calcium is added to water with concentrations of bicarbonates above 2 meq/liter, calcium carbonate may precipitate. Sulfates in fertilizers can react with calcium in the water resulting in the precipitation of gypsum. These precipitates can clog emitters.

Phosphorus- and sulfate-containing fertilizers, if needed, should be applied before planting because we are not concerned about these leaching. Nitrogen is the element that is most appropriate for injection into trickle irrigation water. Calcium nitrate has the potential to cause clogging if the

water pH and bicarbonate levels are high as noted above. If calcium nitrate causes clogging, potassium nitrate or urea can be used as an alternative N source.

Water testing labs can analyze water for pH, calcium, magnesium and bicarbonates. You can also perform a simple test: Mix fertilizer into a container of irrigation water at the same concentration it will be after injection into the trickle system. Cover the mixture to exclude dust and let it sit for at least the length of time it will be in the system before it reaches the soil. If the water becomes cloudy or a precipitate collects on the bottom of the container, you can expect this to happen in the irrigation system with the likelihood of clogging. If it is necessary to lower the water pH, acid can be injected into the irrigation water. This requires special handling precautions and special injection equipment. Be sure to carefully follow directions to avoid personal injury or damage to crops or equipment.

RAISED BEDS

Raised beds provide an optimum environment for germination and growth, especially when used with the stale seedbed technique. Raised beds are formed with special bed shapers. Raised beds improve drainage, but also hasten the drying of soil. Without irrigation, bed height should be restricted to 4". When irrigation is available, bed height can be raised to increase air flow and benefit crops such as lettuce. In areas of heavy rainfall, crops are seeded on beds so that excess water drains off. Yields of vegetables are often increased because the depth of friable soil is greater. Pre-formed raised beds warm up faster and allow for early seeding. Raised beds can also reduce the incidence of Phytophthora root rot and damping off. Herbicides are often incorporated into the soil at the same time or just after the beds are made. Be certain that the herbicide is incorporated to the proper depth. For best results, do not incorporate the herbicide before the beds are made; the herbicide will likely end up too deep and cause crop injury; or concentration can be increased when soil is thrown up while forming the beds.

Wind damage is reduced with raised beds. Level soil has a more pronounced airfoil effect, and with the wind passing over them, this allows for a partial vacuum effect. Soil particles are more easily lifted and seedlings more often twisted. The resulting abrasions on the plant surfaces allow for easier disease introduction if conditions are favorable to the pathogens. Raised beds break up the airfoil effect, reduce the twisting of seedlings and the number of airborne soil particles.

Growers should consider bed direction and the slope of the bed. During cool, spring days, maximum warming of the bed is needed to provide suitable conditions for plant growth. When the days are short and temperatures are low, orient the beds north and south if two rows per bed are used (if soil erosion is not a consideration). If beds are set in an east-west orientation, the rows planted on the south side of the bed get more heat and grow faster than rows planted on the north side of the bed. This can lead to a lack of uniformity at harvest time. However, beds that are oriented across the slope following the contour of the land minimize soil erosion. For instance, on south-facing slopes, beds of spring crops should be oriented east-west.

PLASTIC MULCH AND ROW COVERS

Plastic mulch and row covers are cultural tools that can improve earliness and yields of many vegetable crops. The primary function of these materials is environment modification, and their effectiveness is strongly influenced by the weather during a particular growing season. Row covers can also have pest management benefits. They can be used as a part of an overall production management program.

Plastic Mulch Films

Plastic mulch is generally 1.0-1.5 mils thick, 4-6 feet wide, in rolls 1,000-4,000 feet long. It is available in a multitude of colors ranging from clear (transparent) to opaque (black or brown). Recently, colored mulches have been investigated for their influences on insect control and plant yields. For example, reflective or silver mulches have been shown to reduce the incidence of onion thrips. Check with your local extension office for the most recent research findings proven to work in your area.

Plastic mulch functions to warm the soil, conserve moisture, and prevent nutrient leaching. Clear plastic has the highest soil warming capability (8°-14°F over bare soil), but weed growth underneath can be extreme. An herbicide is necessary to keep weeds under control with clear mulch. Black mulch will prevent weed growth by prohibiting light transmittance to the soil and will warm the soil 3°-5°F over bare ground.

Wavelength selective or near-infrared transmitting mulch (formerly referred to as IRT mulch, but now “IRT” is part of a trade name) is a “hybrid” of black and clear mulch characteristics. Specific pigments incorporated into the film during manufacture selectively block out blue and red wavelengths of light (which cause weeds to grow). This inhibits weed growth similar to black mulch. At the same time, infrared light is transmitted through the mulch warming the soil (similar to clear mulch). The wavelength selective mulches are generally brown or green in color. However, don't purchase them on color alone. The pigments embedded in the plastic impart these specific properties. Commercial recommendations are to lay wavelength selective mulches 7 days prior to transplanting. Within reason, the additional cost for this mulch film is compensated for by increased yields due to early soil warming. On small farms or in small fields, black, brown, or wavelength selective mulches are often the preferred way to eliminate the use of herbicides. This is a viable option for weed control on many organic farms. Crops that respond best to mulching are those that require higher soil temperatures (muskmelon, watermelon, cucumber, squash, tomato, pepper, and sweet corn).

Apply plastic mulch after fields have been leveled, smoothed, and fertilizer has been applied, and when there is good soil moisture. In the case of black mulch, good uniform soil contact is essential as the soil is warmed by heat conduction. Commercially, the simplest way to apply mulch film is with a mechanical mulch layer. Hand application is an option, but applying more than a half-acre can be difficult and time consuming.

Generally, plastic mulch is laid in the spring as soon as the land can be prepared. However, some spring seasons are wet and can delay normal land preparation and planting activities.

An alternative is to lay plastic in the fall. Fall mulch application will require similar land preparation as in the spring, but use of a cover crop between the rows is recommended to prevent soil erosion. Oats will winter kill, but winter rye will require Roundup or Gramoxone applications in the spring to knock down.

After harvest, plastic mulches should be removed from the field and disposed of properly according to local ordinances on incineration, landfills, and open burning. Alternatives to removing plastic from fields are biodegradable mulch films and recycling programs to alleviate landfill accumulations. Research is ongoing on both of these options.

Biodegradable Plastic Mulch

Degradable plastic mulch has been in development for decades. Some of the first commercialized products were photodegradable, and would break down when exposed to light. Many growers who used these products reported uneven and incomplete breakdown, particularly after tillage buried the plastic fragments at the end of the season. However, degradable mulches prepared from biodegradable polymers now exist. They are designed to be tilled into the soil after their service life, after which they will undergo aerobic biodegradation by soil microorganisms, producing CO₂, water, and microbial biomass.

The most widely available and studied biodegradable polymer is Mater-Bi, made in Italy by Novamont. Some mulches that use this polymer are Bio360 and BioTelo (Dubois Agrinovations) and BioAgri (BioBag Americas). Mater-Bi is made primarily from starches, cellulose, vegetable oils plus proprietary biodegradable complexing agents derived from renewable, synthetic, or mixed sources. While Bio360 mulch is approved for use on European organic farms, at this time no biodegradable plastic mulch is approved for use on USDA-certified organic farms. This is because currently available biodegradable plastic mulches have a maximum 25% biobased content while one of the requirements of National Organic Program is that the mulch must be completely biobased. Further, most commercially available biodegradable plastic mulches are produced through fermentation using genetically modified yeast and bacteria for increased productivity, and that is not allowed in US organic agriculture. US organic regulations do allow the use of synthetic (polyethylene) mulches, but they must be removed from the soil at the end of the growing season.

Researchers at Cornell University, Washington State University, and University of Tennessee have shown that the biodegradable plastic mulches performed comparably to polyethylene mulch in controlling weeds, raising soil temperatures and increasing crop yields despite some breakdown of biodegradable mulch during the growing season. As biodegradable mulch starts to degrade during the growing season, mulch adhesion to fruit surface can be an issue for heavy-fruited crops like pumpkin and watermelon, where fruits rest on the mulch for extended period. Up-to-date information can be accessed at www.biodegradablemulch.org.

Biodegradable mulches can range from 2-3 times the cost of standard black plastic, but end-of-season labor and disposal costs are avoided. The mulch is thinner (it comes in 0.5-0.8 mil thicknesses) than typical black polyethylene (1.25 mil), and when starting to lay the plastic, extra care is required to

prevent tears. When laying mulch, do not stretch as tightly as you normally would with black plastic (see mulch installation video at <https://ag.tennessee.edu/biodegradablemulch/Pages/Videos-relating-to-Biodegradable-Mulch.aspx>). Applying in early morning when temperatures are cooler can help. The mulch starts to break down more quickly when stretched. Apply right before planting because the mulch will start to break down as soon as it makes soil contact. Buy what you need each year – do not try to store biodegradable mulch. The mulch can start to break down in storage, particularly if storage conditions are moist and/or warm. Store the mulch upright, on ends of rolls. The mulch can start to degrade or stick together under pressure of its own weight.

WeedGuardPlus (Sunshine Paper Co.) is a brown paper mulch with soil cooling properties. It is OMRI listed and is effective under low rainfall and low wind conditions. WeedGuardPlus is also effective in controlling nutsedge unlike polyethylene and biodegradable plastic mulches. However, it is even more expensive than biodegradable plastic mulch and typically comes in 500 ft rolls.

Slitted and Floating Row Covers

Row covers function to enhance growth and yield by modifying the temperatures around plants in the spring and fall, or in combination with low tunnels, during the winter. There are two general types: slitted or perforated plastic, and spun-bonded fabric. Heavier weight row covers can provide several degrees of frost protection, while lightweight “non-heating” or summer weight covers offer less heat enhancement and can be used in summer for insect protection. These materials can be used with or without hoops (“floating row cover”) depending on its weight and the fragility of the crop underneath. Newer types of knitted or woven lightweight row cover (for example, ‘Proteknet’ by Agrinovations) are becoming available; they can be used with or without hoops, are quite durable, and will exclude insects.

Row covers are installed right after planting and are left covering the crop for several weeks, depending on crop type and season. For fruiting crops and cucurbits, covers can be left in place for approximately 3-5 weeks until pollination is needed or the crop outgrows the space under the cover. Other crops that are low-growing and do not require pollination can remain under cover as long as the temperature benefit is useful. Sweet corn may be left covered with spun-bonded row cover until pretassel stage. If the crop is pressing against the cover, either loosen or remove it. Row cover removal timing is more critical in some crops, such as tomato and pepper, as they cannot tolerate extremely high temperatures that might develop under the covers (especially polyethylene). Covers must be removed for crops requiring insect or wind pollination.

Slitted or perforated row covers are clear polyethylene films with slits cut or holes drilled to provide ventilation when the plastic loosens under hot conditions. Under cool conditions, the plastic is taut and the slits remain closed. Very little water condensation occurs under perforated plastic covers. There is generally less frost protection under slitted or perforated row covers than under a solid cover.

Plastic row covers will require support with wire hoops. A piece of No. 9 wire cut about 65" long makes a hoop that is

about 3' wide at the base and 14" tall in the center of the row after inserting each leg of the hoop in the soil. Secure the edges of the cover with soil.

If you have a diversified vegetable and/or berry operation, row covers can be a cost effective and convenient tool for producing early, high quality crops. Edges are usually held down with soil, soil-filled bags, boards, smooth saplings or tree limbs or rocks. Row covers provide sufficient growth enhancement by raising air temperatures during the day and moderating cold temperatures at night. They also allow light and water to penetrate to the crop. The result is earlier harvests, and in some cases, higher total yields. While row covers do not provide reliable frost protection, they may be helpful when temperatures drop 2°-3°F below freezing. Heavyweight covers can provide more frost protection, but they block much of the sunlight, resulting in slower growth. A key benefit of row covers is that, if they are sealed along the edges, they exclude a wide range of insect pests that can damage crops.

Which types to use? There are several different weights, measured in ounces per square yard or grams per square meter. Materials that are 0.5-0.6 oz/yd² provide growth enhancement and insect control, have high light transmission (85-90%), and are less expensive than heavier materials, but are more likely to rip from wind and sharp objects (fingernails, boots, deer hooves, stakes, etc.). One can expect 1-2 seasons with careful handling. A row cover that is 0.9-1.25 oz/yd² is heavy enough to be more tear resistant and last several seasons, has somewhat lower light transmission (70%), and provides growth enhancement and some frost protection in spring and fall. The heaviest covers are 1.25-2 oz/yd², have lower light transmission (30%-40%), are used mainly for frost protection or for overwintering, and are durable enough to last for several seasons when handled with care. Non-heating row covers are useful when an insect barrier is needed during the hot part of the season.

Support and Fastening. Many crops can handle floating covers without any support, including lettuce, greens, crucifers, onions, potatoes, strawberries, sweet corn. Those with tender, exposed growing points (tomatoes, peppers, and vine crops) should have some support to prevent damage from wind abrasion. Wire hoops or short stakes with a smooth top to prevent tearing provide good support. Secure the edges of the cover with soil, with soil-filled plastic bags, or with metal or plastic pins or staples. For holding the cover in place, soil is the most secure in high winds, but the edges are difficult to unearth after repeated wetting and drying, while soil bags make it easier to lift or move covers and prolong the life of the material.

Widths. Row covers can be purchased in widths ranging 3-60 feet and in lengths 20-2,550 feet. Wider covers are more labor efficient because they have less edge to bury per covered area—but don't try to lay them in a strong wind!

Weed control. Watch for weed growth under the cover because they provide a good environment for weeds too. Covers can be rolled to the edge of the bed for cultivation, and then replaced.

Storage. Row covers should be stored away from direct sunlight as soon as they are removed from the field. While many have been treated to reduce UV degradation, they will

last longer if unnecessary UV exposure is prevented. Fold or roll covers in a systematic way so they can be carefully unfolded for next year's use.

Insect Control. Only use covers on rotated fields because some insects overwinter in the soil and could emerge under the cover. Also, seal the edges of the cover immediately after installation. If you pull it back for cultivation, do so when insects are less active, such as on a cloudy day or in the morning.

Insects That Can be controlled by Row Covers

Cabbage root maggot fly. This pest is a concern in spring or fall crucifer crops. Pupae overwinter in the soil wherever they fed on fall brassicas. First generation adults fly from late April to mid-May and lay eggs at the base of the crop stems. Maggots feed on roots and kill early cole crop seedlings. Immediately after planting, place spunbonded row covers in the field and seal the edges to keep cabbage maggots out. It is important to rotate crops as pupae can overwinter in the soil and flies may emerge under the row covers and damage the crop.

Flea beetles. There are many different species of flea beetles, each with a specific host crop. Because they typically spend the winter as adults around field edges, they can be effectively excluded by row covers if covers are in place soon after planting. Crucifer and striped flea beetles are tiny, black or striped beetles which cause shot-hole feeding patterns on any of the cabbage family crops. Covers can be used with spring or fall transplants, or all summer on direct-seeded crops, but are too hot for transplants in midsummer. Potato flea beetle causes similar damage to eggplant, tomato, and potato. Corn flea beetles cause feeding damage but are primarily a concern because they vector Steward's wilt. Excluding beetles with row covers prevents infection of young corn plants.

Spinach leaf miner. Insect pest in spring spinach, beets, and chard. This slender black fly emerges from overwintering sites in the soil and lays small eggs in the underside of leaves. Maggots tunnel inside the leaf, making unsightly pathways that render greens unmarketable. Row covers prevent flies from laying eggs on the leaves.

Striped cucumber beetle. Insect pest in melons, summer squash, cucumber, winter squash, and pumpkins. Row covers prevent feeding damage and transmission of bacterial wilt vectored by the beetle. Remove when flowers appear to allow for pollination by bees.

European corn borer. Adults emerge in late May or early June and lay eggs on corn. If row cover is left on into mid- to late June, after flight is peaked, it provides excellent protection to corn. If removed just as flight starts (e.g., first week in June) the larger, healthy corn that was covered may be just as infested as corn that was never covered. Row covers can be left on until tassel if enough slack is left for 3 to 4 feet of stalk growth.

Colorado potato beetle. This insect moves into potatoes and eggplant in late May and early June. Row covers should be removed before tuber initiation, which usually coincides with flowering, to prevent excessive heat.

Potato leafhoppers (PLH). Adults migrate from southern states where they overwinter. Adults usually arrive, reproduce and

damage beans, potatoes and sometimes eggplants in June and July, but may last until September. Feeding causes a symptom known as hopper burn, where tips and edges of leaves begin to yellow, curl and die back. Adults and nymphs hide on the underside of leaves. Row covers can be used on beans from emergence until bud stage or the start of bloom. If removed for bloom, damage can be avoided and yields maintained. Lightweight row covers can also be used on potatoes to exclude PLH, flea beetles and Colorado potato beetles.

HIGH TUNNELS

High tunnels are greenhouses without permanent foundations that are used to extend the growing season and enhance the environment for crop production.

Site Selection

Avoid sites with inconvenient access, excessive water, poor quality soil, high winds, or low light levels. Ideally tunnels have year-round access, even when crops are not being grown, to allow for snow removal and other maintenance. Existing or potential access to irrigation water is essential, and access to electricity is desirable for inflation fans and mechanical air movement, although some growers have made use of micro-solar power systems to support these loads. It's desirable to have good access roads and be close to wash/pack facilities. When siting your first tunnel(s) keep in mind future tunnel locations, so that your "build out" over the years allows for efficient access, materials handling and potential for multi-tunnel heating systems, etc.

The site's topography should allow for drainage of "worst case" storm water and snow melt away from tunnels. A relatively level site is important to minimize structural stress on the tunnel due to uneven snow load. Moderately breezy sites can be helpful for passive ventilation, but high-wind sites create risk of damage to structure and/or plastic covering. Trees can provide a windbreak but consider their future height when locating tunnels to avoid shading and also note that dense hedge rows or locations too close to wooded areas can reduce passive ventilation.

Tunnels should be slightly elevated compared to the surrounding soil in order to allow water running off the cover to drain away from the interior, and to allow snow melt to move away from the tunnel when the ground is frozen. On some sites it is advisable to create a raised pad for tunnels. Some growers install tile drainage, French drains, or curtain drains along the inside or outside of tunnels to carry excess water away from growing areas. Water running through/under a tunnel takes away soil heat, prevents good root growth, and can create muddy working conditions. Orienting tunnels along east-west axis provides optimal light for winter production, and a north-south axis is best to avoid shading inside the tunnel in other seasons, though most crops will have more light than they can use in the summer.

Construction

Do not skimp on the structural integrity of tunnels, as this can lead to collapse in bad weather. Plan for extreme snow and wind. Well-set ground posts, cross-ties, and other features that anchor the tunnel and keep it rigid are essential.

Doors and vents should close securely to prevent winds from opening them in storms and seal well to help retain heat. When building a tunnel, avoid driving equipment over future growing areas, as this can create compaction. Installing large doors in end walls or having removable / roll-up end covers to allow for tractor access can make tillage and addition of bulk soil amendments easier than with small equipment. Head houses or other structures make sense for tools and equipment, seed, potting soil rather than taking up valuable growing space in the tunnel.

Zoning and codes

Before you build, contact your state and local agencies to find out about regulations and tax policies for high tunnels. Some states and towns may require building permits; setback requirements and building codes vary among municipalities. Some consider tunnels to be real property (subject to tax) and others do not. It may be helpful to be very clear with local officials that the structure is not permanent and is used for producing agricultural crops.

Soil quality

As in the field, tunnel crop production will benefit from deep, well-drained, fertile soil that is not compacted. On most sites, soil amendments such as compost, peat moss or coir will be desirable to increase the organic matter level to optimize tunnel production. Lime and nutrients should be added based on soil tests prior to production. Fertilizer recommendation should be calibrated to the higher yields and longer growing season expected in tunnels compared to the field. On sites with poor native soil, compaction and/or drainage problems, soil can be imported either into the entire tunnel, raised beds, containers or by using 'grow-bags' of pre-fabricated media.

Since tunnel soils are not exposed to regular leaching from rainfall, soluble salt levels can build up over time negatively affecting plant growth. Salts dissolve into ions in soil solution and come from the application of fertilizers and composts or manures. Crops remove some of these salts in their tissues, but the excess remains in tunnel soils, unlike in the field. Strawberry, green beans, and certain herbs are very sensitive to salts, but even tolerant crop such as tomato and spinach can show reduced vigor with very high levels. Salts tend to accumulate especially in the top few inches of soil, as they move upwards with evaporation and can effect germination of winter crops while transplanted crops such as tomato may be more tolerant to high salt levels. Deep tilling will remix those salts into the soil profile. Salt injury can be exacerbated if soils are allowed to dry out. Excessive salts can be reduced by diluting with the addition of peat moss, coir or topsoil. Irrigating with a large amount of water can move salts down in the soil profile, but is often impractical. Removing the plastic cover over winter is perhaps the easiest way to leach salts out of the root zone.

Ventilation

Air exchange in tunnels is essential to avoid high temperature, high humidity, and low CO₂ in tunnels, leading to plant stress or disease. Passive ventilation using roll-up sides is common in tunnels, though some tunnels use mechanical ventilation with fans to pull air through the tunnel. Generally, you must pick one or the other or use them at

different times. Fans pull from the point of least resistance, so running an end-wall fan with the sides rolled up simply pulls air from around the corner, not from the other end of the tunnel. When sizing fans for ventilation the basic rules of thumb are 8 CFM/ft² (of growing space) for summer cooling and 2 CFM/ft² to remove humidity during cooler months. Note that this guidance is for peak ventilation needs. Staged fans (e.g., one small, one large) or variable speed fan controls can help moderate the ventilation for various times of the year.

Passive ventilation is less than ideal in locations where tunnels are crowded together, there are lots with trees or other significant wind breaks, or in calm sites with little wind. A dense crop canopy later in the growing season also reduces passive ventilation.

Installing a ridge-vent (along the top peak of the tunnel roof) will greatly increase the effectiveness of passive ventilation, though these can be costly and they make installation of plastic cover more complicated. Some growers who have ridge vents have installed "cat walks" to ease maintenance. These can make plastic replacement and repairs easier. Gable vents high up on end walls can also improve ventilation by acting as outlets for warm humid air in warmer seasons and by allowing for low volume ventilation in colder weather. A 24"x24" gable vent on each end wall is recommended for a 30'x96' tunnel. These can be made of plywood and manually operated with hinges, ropes or cables and tie-downs. If using a louvered vent, be sure it has a flanged seal to close against. Thermostatic wax cylinder actuators may also be used which require no electricity, are relatively inexpensive and are passively controlled by the wax cylinder based on temperature.

HAF Fans

Horizontal air flow (HAF) fans are hung from the inside horizontal structural tubing to mix the air inside a tunnel to create consistent growing conditions, they don't improve ventilation. They are for circulating and mixing the air inside the tunnel. When installed and used properly, they ensure that plants and any control sensors are seeing the "average" conditions of the space. The first fan should be placed about 10'-15' from one end wall to pick up the air that is coming around the corner from the other side. Subsequent fans should be located 40'-50' apart to keep the air mass moving. In a 30'x100' greenhouse, four fans are required, and the total fan capacity should be 6,000 CFM (2 CFM/ft²). The "empty" corner, where there is no fan can sometimes become a spot without air flow. Check to make sure you can feel air flow in all locations in the house. You may have to add fans or reorient the ones on the end to promote adequate mixing flow. If a tall crop such as tomatoes is grown or if there are hanging baskets, a slightly greater capacity is needed to overcome the additional air flow resistance. Small, 1/10 to 1/15 horsepower circulating fans work well in providing the air movement needed. A permanent split capacitor motor can save as much as one-third the electricity of the more common shaded pole motor. Some growers have used inexpensive, simple box fans and just plan for frequent replacement. High efficiency vane-axial fans can increase the "throw" of each HAF fan meaning you need fewer fans to provide the same mixing flow.

Tunnel covering

Typical high tunnel covering is greenhouse grade 6 mil polyethylene rated for 5 years. Using two layers, separated by air blown between the layers, reduces heat loss during cold season production and provides stability under windy conditions, reducing damage to the plastic. Solid plastic “spacers” are available to separate two layers of plastic in locations without electricity. Some greenhouse plastics have additives to enhance durability and performance. UV stabilizers are essential to slow degradation of plastic. Anti-fog and anti-drip surfactants make water condense and run down to the sides of the structure, rather than bead and drop on the plants below. IR radiation-blocking additives reduce heat loss at night. UV-absorbing films have the potential to suppress certain insects and diseases. In summer, plastic may be covered with shade cloth to reduce light intensity and temperature. Shade cloth is rated by the percent of light blocked. Whitewash is also used by growers to help keep tunnels cool in summer.

Heating

When it’s cold outside, growers may want to heat the air and/or soil inside a tunnel, and this can be done using permanent heating systems, or emergency systems for coping with unusual conditions. Whatever system is used, a temperature warning system is important to provide notification when heating (or cooling) is urgently needed. To determine what size heater is needed, one must calculate the heat loss when a certain minimum temperature is desired inside the tunnel when there is a certain outside temperature. More information on heating, ventilation, and other engineering issues can be found at the University of Massachusetts greenhouse and floriculture web site and on the University of Vermont Extension agricultural engineering blog.

Irrigation

Water must be provided to replace that lost by evapotranspiration (ET), the combination of soil surface evaporation and water loss from plant leaves. Drip irrigation is an efficient way to deliver water and nutrients in tunnel, keeping the foliage dry, which reduces disease pressure. Drip tape is usually 8-10 mil thickness and is laid on the surface or buried an inch or two. Flow rates of drip tapes vary, a medium-flow tape provide 0.5 gpm per 100 feet. High-flow tape with 1.0 gpm flow is useful to prevent clogging and reduce irrigation time. Drip lines should be spaced on the soil surface to assure that the entire bed or row is wetted. Light-textured soils have less capillary movement of water than heavier soils, so more drip lines may be needed to prevent dry areas in the bed in which roots will not grow. Many systems are available to add soluble fertilizer to irrigation water. Fertigation is a good way to provide plants with the nutrients they need over the season, or to supplement fertilizers applied at planting. Irrigation water quality should be tested. Water with high pH and high alkalinity may lead to increased soil pH over time.

A mature crop of tomatoes may require 2.5 quarts of water per plant per day, whereas winter greens may grow well only on existing soil moisture, and if irrigated, may develop disease. Determining the optimal amount and timing of

irrigation is complicated since it depends on the crop, its stage of growth, soil texture, sunlight, temperature and humidity. Use of soil moisture sensors placed at several locations and depths in each tunnel, combined with irrigation and crop performance records can help determine best practices on your farm.

Pest management

The tunnel environment differs from the field, so the type and timing of insects and diseases also differs. For example, spider mites and aphids are more frequent pest in tunnels than outdoors, and foliar diseases are typically more problematic in tunnels due to humidity levels. The use of biological insect controls is more practical in tunnels than outdoors due to the enclosed space, high crop value, and extensive information developed for many crops. See the University of Vermont’s high tunnel pest management web site for more information. Maintaining the area around the perimeter of the tunnel with mowing and trimming is a passive way of minimizing mammalian pests by reducing cover.

Pesticides

Outdoors, pesticide residues break down after application by exposure to ultraviolet radiation and rainfall. Inside tunnels, plastic coverings reduce U/V and rain, and as a result, pesticides break down differently. Each state’s pesticide regulatory agencies may have different interpretations of whether high tunnels are considered open fields or greenhouses, however it is safest to consider a high tunnel a greenhouse from the perspective of pesticide labels. The label may 1) specifically state that the product may be used in greenhouses and may provide different guidelines for greenhouse and outdoor use, 2) specifically state that the product may not be used in greenhouses, or 3) may not mention greenhouse use at all. The Environmental Protection Agency’s current position is that, a label does not have to specify greenhouse as a site, provided the crop is on the label, in order to use the product in a greenhouse. If the label has multiple sections, and one of those sections is for greenhouse application, then the label must be followed explicitly for greenhouses with no exceptions. The rate for outdoor applications on those crops is for outdoor use ONLY and CANNOT be used for those crops in the greenhouse, since those crops were not included in the greenhouse section of the label. Using a pesticide inside a greenhouse where the label does not mention greenhouse use can increase risks to workers or plants. Also, when using a fumigant or smoke generator for an entire greenhouse, every crop in the greenhouse must be listed on the product label. We advise against applying a product in high tunnels unless the label specifically allows its use in greenhouses.

ESTIMATING VEGETABLE YIELDS

Yields vary a great deal due to climate, growing conditions, soil quality, and farm management. To estimate yield in a consistent manner, one can harvest 10' of row at several locations in the field. Multiply the average yield (lb) per 10' of row times the following row spacing factors to convert the sample yields to lb/A. See Table 14 and Table 15.

Table 14: Estimating Vegetable Yields

Row Spacing in Inches	multiply by	Row Spacing in Inches	multiply by
12	4360	30	1740
15	3480	36	1450
18	2900	42	1240
20	2610	48	1090
21	2490	56	930
24	2180	60	870

POSTHARVEST HANDLING AND STORAGE

Harvested vegetables are living things that carry on the process of respiration and other biological and chemical processes. How produce is handled after harvest will directly affect quality characteristics such as appearance, flavor, texture and nutritional value. Attention to postharvest quality can increase repeat sales and support higher prices.

Control of postharvest quality essentially comes down to limiting respiration rate (lowering temperature), controlling water loss (maintaining proper relative humidity), minimizing physical damage to the product (harvesting and handling with care), and avoiding contamination (handling, washing and storing appropriately).

Limiting Respiration

Respiration is a temperature dependent biochemical process that converts carbon in plant tissue (mainly sugars) to carbon dioxide (CO₂) and water (H₂O) while producing some heat. Rates of respiration vary by the crop (see Gross 2016, Table p. 7 and pp. 68-75 in references at the end of this chapter), and should be taken into account when sizing cooling equipment. Fortunately, we can significantly reduce respiration, and therefore maintain high product quality, by reducing product temperature (precooling) and keeping it low (holding or storage cooling). This concept is known as establishing the “cold chain”; a chain of reduced temperature that connects the field to the consumer ensuring the highest quality produce possible by minimizing respiration.

From the moment of harvest, product quality will deteriorate. Intentional precooling of produce directly after harvest helps quickly reduce the rate of respiration and initiates the cold chain. Examples of precooling include scheduling harvest activities at cooler times of day, shading harvested product in the field prior to transport, forced air cooling through the packed product with refrigeration, hydrocooling with cool water, and vacuum cooling via evaporation. Once cooled to storage temperature, reliable, refrigerated storage is necessary to maintain high quality.

It is important to note that not all crops can be cooled to the same temperature without resulting in cold or freeze injury and some crops are sensitive to the method of cooling. Crops have different susceptibility to chilling or freeze injury depending on their physiology. Good guidance is available (see Gross 2016, p 62-67) and is summarized in Table 16 of this guide. Common precooling methods are also noted in Table 16. Additionally, a computer based crop storage planner is available for determining appropriate grouping of your crops and estimating overall respiration load (see Callahan 2016). Chilling injury is also an important

consideration when considering particularly sensitive Fall harvested crops and the possibility of lower nighttime temperatures, e.g. winter squash. Notes on chilling injury guidance for these crops are provided in the appropriate crop chapter and in the references above.

Controlling Water Loss

The control of water loss requires careful attention to relative humidity (RH) of the air surrounding stored product in addition to temperature. RH is a measure of the amount of water vapor in air compared the maximum amount that can be saturated in that air at a given temperature. Most, but not all, crops are ideally stored at higher RH to prevent water evaporation into the air leading to water loss. The loss of water reduces the weight of the crop and also can lead to lower quality and poor appearance.

Some crops, such as onions, garlic and winter squash, are purposefully “cured” or dried resulting in drier outer skin and curing harvest wounds to allow long term storage. Because this results in a paper-like layer, these crops are generally stored at lower RH to prevent development of postharvest disease such as molds and fungi on this outer skin. Other than these examples, most crops are best stored at 90%-95% RH with specific guidance provide in Table 16, in the crop storage planner noted above, and in the literature (see Gross 2016).

Minimizing Physical Damage

Generally speaking, produce crops live a very gentle life until harvested. Starting with harvest, produce is moved and handled for the first time and, typically, many times after. With each movement there is a risk of physical damage. Even if the damage is not obvious, it can result in bruising or other damage that becomes evident later and can led to postharvest disease and pathogens which are encouraged by damaged cell tissue. Even during harvest, crops can suffer “harvester blight.” For the majority of crops, gentle handling, crates with smooth and clean surfaces, and conveyance with elastic and soft belts and rollers should be used.

Avoiding Contamination

Sorting and culling are also important practices at this stage. As the saying goes, “one bad apple can spoil the bunch”. Sorting allows for different sizes and grades of product to be stored and sold separately and culling can separate damaged or lower quality product from the main lot for sale, rescue donation or compost depending on the defect. The removal of obviously damaged product from the lot helps minimize cross contamination postharvest pathogens to a larger portion of the population.

Produce can be rinsed to remove soil and debris, and often a sanitizer is added to the rinse water to prevent cross-contamination of plant and human pathogens from one item of produce to another in the same batch (see the following references: LaBorde, Samuels and Stivers 2016, Bihn et al. 2014).

Once packed and ready for storage or transport, care should be taken to avoid contamination of product with other contaminants such as foreign matter and unintentional water such as condensate from refrigeration systems.

Table 15: Approximate Yields					
Adapted from Knott's Vegetable Grower Handbook, The New England Vegetable Growers Yield Guide Table, United Fresh Fruit Market Containers and Weights, The Boston Fresh Vegetable Wholesale Market and Arrivals Report, and the USDA-National Agricultural Statistics Service New England Vegetable and Strawberry Report (2014-2018).				Abbreviations for Vegetable Yield Table	
				bun. = bunch	lb. = pound
				qt. = quart	pt. = pint
				bu. = bushel	wt. = weight
				doz. = dozen	
Vegetable	CONTAINER OR UNIT	YIELD PER ACRE*			
		LOW	GOOD	EXCELLENT	NEW ENGLAND 5-YEAR AVERAGE
Asparagus	20 lb box	1,600 lb	2,000 lb	4,000 lb	1,420 lb
Basil	24 ct; 12 lb	3,000 lb	4,000 lb	6,000 lb	-
Beans, snap	1 1/9 bu box; 20 lb	4,000 lb	8,000 lb	10,000 lb	3,320 lb
Beets, red bunched	24 ct; 40 lb box	20,000 lb	24,000 lb	30,000 lb	7,080 lb
Broccoli	14 ct bun; 20 lb box	5,000 lb	8,000 lb	10,000 lb	3,615 lb
Cabbage	1 2/3 bu box; 50 lb	20,000 lb	30,000 lb	40,000 lb	15,240 lb
Cantaloupe / Muskmelon	12-16 ct 1 1/9 bu box; 40 lb	8,000 lb	16,000 lb	20,000 lb	7,340 lb
Carrots	50 lb bag	20,000 lb	26,000 lb	30,000 lb	11,500 lb
Cauliflower	12 ct 1 1/9 bu box; 25 lb	8,000 lb	14,000 lb	20,000 lb	4,640 lb
Corn, sweet	5 doz bags; 50 lb	750 doz	1,000 doz	1,500 doz	750 doz
Cucumber	1 1/9 bu box; 40 lb	12,000 lb	20,000 lb	26,000 lb	9,120 lb
Eggplant	1 1/9 bu box; 25 lb	16,000 lb	20,000 lb	24,000 lb	9,730 lb
Endive/Escarole	24 ct 1 1/9 bu box; 20 lb	21,000 lb	23,000 lb	26,000 lb	-
Garlic	1/2 bu box; 10 lb	2,000 lb	4,000 lb	6,000 lb	2,240 lb
Kale/Collards	24 ct bun 1 3/4 bu box; 20 lb	10,000 lb	12,000 lb	18,000 lb	12,996 lb
Kohlrabi	25 lb bags	14,000 lb	20,000 lb	30,000 lb	-
Leeks	12 ct bun 3/4 bu box; 15 lb	28,000 lb	32,000 lb	36,000 lb	-
Lettuce, leaf	24 ct 1 1/2 bu box; 25 lb	26,000 lb	29,000 lb	33,000 lb	6,970 lb
Lettuce, head and romaine	24 ct 1 3/4 bu box; 35 lb	36,000 lb	40,000 lb	46,000 lb	7,879 lb
Onions, dry bulb	50 lb bags	30,000 lb	40,000 lb	50,000 lb	9,580 lb
Onions, green bunch	24 ct bun 1/2 bu box; 10 lb	16,000 lb	18,000 lb	20,000 lb	5,400 lb
Parsley	30 ct bun 1/2 bu box; 12 lb	12,000 lb	16,000 lb	20,000 lb	-
Parsnip	25 lb bag	16,000 lb	20,000 lb	26,000 lb	-
Pea, snap	varies	3,000 lb	6,000 lb	8,000 lb	2,220 lb
Pea, pod	varies	6,000 lb	9,000 lb	14,000 lb	-
Pepper, bell	1 1/9 bu box; 25 lb	23,000 lb	30,000 lb	37,000 lb	10,600 lb
Potato, Irish	50 lb bag	15,000 lb	25,000 lb	35,000 lb	33,824 lb
Potato, fingerling	5 lb bag	10,000 lb	15,000 lb	20,000 lb	-
Pumpkin	20 bu bin; 1,000 lb	30,000 lb	36,000 lb	40,000 lb	10,360 lb
Radish	24 ct bun 1/2 bu box; 10 lb	4,000 lb	6,000 lb	10,000 lb	-
Rhubarb	3/4 bu box; 20 lb	10,000 lb	14,000 lb	18,000 lb	-
Rutabaga	25 lb bag	30,000 lb	36,000 lb	40,000 lb	17,400 lb
Spinach	loose 1 1/9 bu box; 10 lb	8,000 lb	12,000 lb	14,000 lb	3,940 lb
Squash, summer	1/2 bu box; 20 lb	20,000 lb	30,000 lb	40,000 lb	10,030 lb
Squash, winter	1 1/9 bu box; 40 lb	24,000 lb	30,000 lb	40,000 lb	10,030 lb
Sweet Potato	per lb - retail	12,000 lb	15,000 lb	25,000 lb	-
Strawberry	8 qt flat; 12 lb	6,000 lb	10,000 lb	16,000 lb	4,930 lb
Tomato, field	1 1/9 bu box; 20 lb	20,000 lb	30,000 lb	40,000 lb	11,080 lb
Tomato, greenhouse	10 lb box	3 lb/ft ²	4 lb/ft ²	6 lb/ft ²	-
Turnip	25 lb bag	20,000 lb	24,000 lb	30,000 lb	-
Watermelon	1 3/4 bu box; 40 lb	12,000 lb	20,000 lb	24,000 lb	10,040 lb

NOTE: To convert yield per acre to yield per 100 feet of row: multiply yield per acre by the number of feet between rows and divide by 4356.

* Yields vary depending on soil quality, weather conditions, farm management, location, etc. Low, Good and Excellent yields are based on national data, while 5-year averages (2014-2018) are from the USDA-National Agricultural Statistics Service New England Vegetable and Strawberry Report.

Table 16: Handling Produce for Higher Quality and Longer Market Life

Information on optimum temperatures, relative humidity and storage life was adapted from USDA Handbook 66 and modified by experience under northeastern conditions.

Vegetable Crop	Recommended Cooling Methods ¹					Important Handling Factors			
	Forced Air or Room Cooling	Hydro-Cooling	Package Ice or Liquid Icing	Vacuum Cooling	Transit Icing ²	Recommended Transit & Storage Temp. °F ³	Recommended Transit & Storage Rel. Humidity, %	Expected Marketable Life Under Best Conditions	Sensitivity to Chilling Injury ⁴
Asparagus		+		+	N	32-36	95	1-2 weeks	L
Basil	+				N	46-50	90-95	4-7 days	H
Beans, lima	+	+			N	38-42	90-95	7-10 days	M
snap	+	+			N	40-45	90-95	7-10 days	M
Beets, bunched		+			R	32		1-2 weeks	I
Broccoli			+		E	32	90-95	1-2 weeks	I
Brussels sprouts	+	+	+	+	R	32	90-95	3-5 weeks	I
Cabbage	+				N	32	90-95	3-6 weeks	I
Cabbage, Chinese	+		+	+	R	32	90-95	4-8 weeks	I
Carrots, Topped	+		+		N	32	90-95	6-7 months	L
Carrots, bunched	+		+		E	32	90-95	1 month	I
Cauliflower	+		+	+	R	32	90-95	2-4 weeks	I
Celery		+			R	32	90-95	2-3 weeks	I
Collards & kale		+	+		R	32	90-95	1-2 weeks	I
Cucumbers	+	+			N	50	90-95	1-2 weeks	H
Eggplant	+				N	50	90-95	1 week	H
Endive & escarole				+	R	32	90-95	2-3 weeks	I
Kohlrabi	+	+	+		R	32	90-95	2-4 weeks	I
Horseradish	+				N	30-32	90-95	1 year	I
Leeks		+	+	+	R	32	90-95	1-3 months	I
Lettuce, crisphead				+	N	32-36	95	2-3 weeks	I
leaf & bibb			+	+	R	32-36	95	1 week	I
romaine				+	R	32-36	95	1-2 weeks	I
Muskmelon, 3/4 slip	+		+		R	36-40	85-90	1-2 weeks	M
full slip	+		+		R	32-36	85-90	4-7 days	M
Okra		+			N	45-50	95	1 week	VH
Onion, dry					N	32	65-70	1-8 months	I
green		+	+		N	32	90-95	7-10 days	I
Parsley		+	+		E	32	95	1-2 months	I
Parsnips	+				N	32	90-95	2-6 months	I
Peas		+	+		E	32	90-95	1-2 weeks	I
Peppers	+			+	N	45-50	90-95	2-3 weeks	M
Potatoes, early	+				N	40	90	2-4 months	L
late	+				N	40-45	90	5-8 months	L
Pumpkins					N	50-55	70-75	2-3 months	H
Radishes, bunched		+	+		E	32	95	1-2 weeks	L
Rhubarb		+	+		R	32	95	3-4 weeks	I
Rutabagas	+				N	32	95	2-4 months	I
Spinach		+	+	+	E	32	90-95	7-10 days	I
Squash, summer	+	+			N	50	90-95	4-7 days	H
winter	+				N	55-60	50-75	2-6 months	M
Strawberries	+				N	32	95	1 week	I
Sweet potatoes	+				N	55-60	85-90	3-5 months	VH
Sweet corn	+	+	+		E	32	90-95	5-7 days	L
Tomatoes, green	+				N	55-70	85-90	1-3 weeks	H
pink	+				N	50-60	85-90	5-10 days	M
ripe	+				N	40-45	85-90	4-7 days	M
Turnips	+				N	32	95	4-5 weeks	I
Turnip/mustard tops		+	+	+	E	32	90-95	1-2 weeks	I
Watermelons	+				N	45-50	85-90	3-4 weeks	M

¹ Cooling Method: + = cooling method is suitable for the crop.

² Transit Icing: The importance of transit icing depends on time in transit, transit conditions, and outside temperature. N = not recommended, R = recommended, and E = essential.

³ Accurate temperature control is essential; do not allow temp to fall below 32°F

⁴ Sensitivity to Chilling Injury: I = insensitive, L = low sensitivity, M = medium sensitivity, H = high sensitivity, and VH = very high sensitivity.

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PRODUCE SAFETY

While the United States enjoys one of the safest food supplies in the world, the Centers for Disease Control estimates that 1 in 6 people gets sick from a foodborne illness each year, with fresh produce accounting for nearly half of these illnesses. Produce encounters many opportunities for microbial contamination with fecal pathogens during growing, harvest, and distribution, whether through direct exposure to manure or through contact with contaminated water, soil, containers, equipment, or workers. Fresh produce is frequently eaten raw and so may not undergo heating or other processing that would kill pathogenic organisms. Preventing produce from coming into contact with these organisms is the best way to prevent foodborne illness related to fresh produce.

Good agricultural practices, or GAPs, are those practices that help to reduce exposure of produce to disease-causing microbes. In New England, buyers are requesting and, in some cases, requiring that growers become certified by a 3rd-party audit program to demonstrate that they are following GAPs. These programs include the USDA's GAP and Harmonized GAP audit programs, as well as state programs such as Commonwealth Quality (CQP) in Massachusetts. In 2011, the Food & Drug Administration passed the Food Safety Modernization Act (FSMA), which focuses on preventing rather than responding to contamination within the food supply. It consists of seven rules, including the Produce Safety Rule, which sets standards for the growing, harvesting, packing, and holding of produce for human consumption. Of the seven rules, the Produce Rule is the one most likely to impact fruit and vegetable growers. It became effective in January 2016. Affected growers will need to be compliant with the rule between 2018 and 2020, depending on their annual gross income. FSMA's Produce Rule is enforced at the state level, and each of the six New England states has their own enforcement

models. Responsible agencies are listed below. Contact the agency in your state for more information on food safety regulations and best practices, and your responsibilities under FSMA:

Connecticut: Connecticut Department of Agriculture

Maine: Maine Department of Agriculture, Conservation and Forestry

Massachusetts: Massachusetts Department of Agricultural Resources

New Hampshire: New Hampshire Department of Agriculture, Markets, and Food

Rhode Island: Rhode Island Department of Environmental Management

Vermont: Vermont Agency of Agriculture, Food & Markets

Efforts to prevent contamination of produce should be focused on the following key hazard areas. Be aware that FSMA's Produce Rule sets specific requirements for covered farms with respect to water quality and testing, worker training, and other aspects of production and handling. Refer to the FDA's Final Rule on Produce Safety or contact your state Extension or responsible regulatory agency for more information.

Agricultural Water

Water is used in many ways on a farm and is a primary vehicle for the movement of pathogens. Agricultural water can be divided into two groups: production water and postharvest water. Production water is water that contacts the harvestable portion of a crop and includes any water used for irrigation, crop sprays, or frost protection. Postharvest water is any water used during and after harvest and includes water used for produce washing, commodity movement, cooling, ice making, postharvest fungicide applications, handwashing, and cleaning and sanitizing of food contact surfaces.

Consider the source of your agricultural water and how the water will be used in order to manage potential contamination. Surface water, including rivers, streams, lakes, ponds, man-made reservoirs, and any other water source that is open to the environment, is the most risky agricultural water. Water quality from surface water can vary greatly between sites and over time. Some major contamination risks include wildlife, water runoff from upstream livestock operations, and wastewater discharge. Untreated surface water should never be used for postharvest applications and should be monitored carefully when used as production water. Ground water, or well water, is less risky than surface water for agricultural uses, but the potential for cracked well casings and leaky septic systems increases the risk that ground water can become contaminated. Public water supplies are monitored and treated by municipalities and are the least risky sources of agricultural water, though water still may become contaminated within your distribution system. It is important to be aware of the risks to the microbial quality of agricultural water and to keep contaminated water from contacting produce.

Routinely test agricultural water for generic *E. coli* to get an indication of its microbial quality. Test both at the source and at the output to test for contamination within the

distribution system. Production water should be below 126 CFU/100ml for generic *E. coli* and postharvest water should be potable, or have 0 CFU/100ml. Keep potentially risky water from contacting the harvestable portion of a crop. This may mean switching from overhead irrigation to drip irrigation, or for postharvest applications, using single-pass water (e.g. spray from a hose, conveyer, or barrel washer) instead of recirculated or batch water (e.g., from a recirculating conveyor or dunk tank). Recirculating water can become contaminated and present a cross-contamination risk, and must be maintained to be of adequate quality. Sanitizers labeled for use in produce wash systems can help reduce the risk of cross-contamination in recirculated water and can help reduce the build-up of microbes and biofilms in single pass systems. Be aware, though, that sanitizers are pesticides and must be labeled for their intended use and handled and monitored carefully.

Worker Health, Hygiene, & Training

People can easily move pathogens around the farm and onto produce through dirty hands or clothing. Good hygiene and regular, proper handwashing can prevent produce contamination. Make clean, well-stocked, readily accessible toilets and handwashing stations available to workers and farm visitors at all times. Ensure that anyone working around produce maintains personal cleanliness and that all employees know how and when to wash their hands.

Educate your employees with the information they need for their particular job regarding food safety and empower them to make informed decisions about contamination risks. An employee who only harvests produce will need different information than an employee who works full time in the wash/pack house. Ensure that your employees know how to identify potentially contaminated produce or food contact surfaces and know what to do if produce becomes contaminated or if they or another employee is sick.

Postharvest Handling & Sanitation

Good housekeeping in wash and pack areas can help prevent produce from becoming contaminated. Keep postharvest areas clean and organized and encourage workflow that reduces overlap between washed and unwashed produce, containers and equipment. Keep produce handling areas separate from other farm activities such as tractor repairs, pesticide mixing, or employee break areas. Bacteria thrive and multiply in water, so allow equipment to dry and minimize standing water with good drainage and/or routinely clearing pooled water. If your packing area is outside, be sure that area drains well. A gravel pad can help with drainage and soil splash. Keep pests from entering produce wash, pack, and storage areas and establish a pest management program, if necessary.

In addition to general cleanliness, it is important to know how to clean and sanitize tools, equipment, and surfaces effectively. While cleaning and sanitizing should be focused on food contact surfaces—any surface that comes into physical contact with produce—you should also clean and sanitize “secondary” surfaces that may indirectly contact food or food contact surfaces. Cleaning and sanitizing refer to separate actions. Cleaning refers to the physical removal of dirt and organic matter from surfaces, using water and a detergent. Sanitizing is the treatment of a cleaned surface to

reduce or eliminate microorganisms. A dirty surface cannot be sanitized—cleaning always comes first.

Soil Amendments

Food safety risks regarding soil amendments generally involve raw manure, or other untreated animal-based soil amendments. All animal-based soil amendments can contain pathogenic microorganisms if they are not processed in a way that kills such pathogens. If you use composted manure on your farm, you need to ensure that the manure is composted correctly and fully. Otherwise, it should be used as raw manure.

In the fall, if applying manure to land in food production, do so preferably when soils are warm (over 50°F), non-saturated, and cover-cropped. In spring, incorporate manure at least two weeks prior to planting. Whenever possible, incorporate manure. Maximize the time between application of manure and harvest—a good guideline is the National Organic Program Standard of a 90-day interval for crops that do not touch the soil and 120 days for crops that do. Keep records of all manure and fertilizer application rates, source, and dates. Avoid planting root or leafy crops if manure is applied in spring.

Never side-dress food crops with fresh solid manure, slurry manure, manure ‘tea’ or any mulches containing fresh manure. However, it is ok to side-dress with mature compost. A mature compost is one that has been thoroughly heated, turned several times, and allowed to age for a long enough time that it is virtually odor-free and is not objectionable to handle with bare hands. If you do not have records or certification that compost was properly treated to control pathogens, handle it like raw manure and observe the suggested 90- or 120-day application interval.

Wildlife, Domesticated Animals, & Land Use

Animals on farms are food safety concerns because they can carry certain human pathogens (e.g., *Salmonella*, *Listeria*, and *E. coli*) and can spread those pathogens through fecal matter directly to produce in fields, or indirectly through water sources. Avoid grazing livestock near produce fields and keep pets out of production areas. It is impossible to exclude all wildlife from produce fields, but minimize wild and domestic animal traffic by use of fences, scare devices or other means. Never harvest produce that is or that you suspect to be contaminated with animal excrement.

Farm Food Safety Plans & Traceability

Accurate recordkeeping and documentation of practices are essential for ensuring that the risk management strategies described above are done consistently and effectively. A farm food safety plan can help you to compile relevant food safety documents such as risk assessments, standard operating procedures, training information and record keeping logs that can together help you to identify areas on your farm that pose the greatest risk and address them. A food safety plan may also be required by buyers or by regulatory or 3rd-party audit programs. Your plan may include a traceability program to help you track your produce one step forward and one step back within the distribution chain in order to quickly respond in the case of a foodborne illness incident. Tracking produce requires the definition of a “lot” or distinct and limited portion of a crop and a code for identifying that lot. Lot codes should be a

unique code for the identifying characteristics of a lot—for example, the crop and variety name, field or block of origin, and the harvest and packing date. This code will help you identify a particular lot once it has been sold in case you wish to remove your product from the market for any reason, as well as describe it with important information that may help in the case of an investigation.

ORGANIC CERTIFICATION

Federal legislation requires certification of agricultural products that are labeled as organic. Producers whose gross sales of organic products are under \$5,000 must know and meet the USDA/National Organic Program Regulations (<https://www.ams.usda.gov/rules-regulations/organic>), but are not required to seek certification. These small scale producers are encouraged to get certified for marketing benefits. Farms selling more than \$5,000 of products labeled as organic must be certified by a certifier that is accredited by the USDA National Organic Program. See below for a list of certifying organizations in New England currently accredited by USDA.

National Organic Standards

Organic agriculture is based on the use of practices and inputs that enhance the physical, biological and chemical aspects of the soil and its ability to sustain crop and animal production in an environmentally safe manner. Natural sources of crop nutrients and cultural practices that build or maintain fertility are required by the National Organic Standards. Organic agriculture relies on cultural practices as much as possible for pest management, but allows natural based pesticides when needed. In general, the use of synthetic substances for pest management is prohibited, although some synthetic materials are allowed and these are noted in Section 205.601 of the USDA National Organic Program Standards.

This Guide includes information on many organic practices and materials approved by the National Organic Program. See information on sources for crop nutrients in the section Guidelines For Organic Fertility Management, page 18. Compost use is discussed in the section Fertilizers and Soil Amendments. Approved methods of managing weeds, insects and diseases are noted in the Pest Management section. Organically accepted practices are also included in the specific crop chapters.

Organic Material Review

The grower is responsible for determining whether materials are allowed under organic standards. Sometimes this may be a challenge because some materials labeled as organic by the manufacturer may not actually meet the standards of the National Organic Program or by the 3rd-party organic certifier. The Organic Materials Review Institute (OMRI) is recognized by the USDA National Organic Program as an organic material review organization. OMRI publishes a list of products suitable for certified organic production. These products are generally allowed, but some are regulated and subject to restrictions. It is the responsibility of the grower to know the restrictions on product use. In some cases, OMRI notes that certain formulations of a product are permitted and others are not. The list of substances approved by OMRI is subject to change. For the most up-to-date OMRI list, visit

the OMRI web site at: www.omri.org. If using a product not on the OMRI list, be sure to check with your certifier in advance to be certain that the materials and practices you plan to use are approved by your certifier, and that you understand any restrictions on use.

When mentioned in tables or in crop chapters, this Guide designates approved organic materials with a superscript OG ^(OG), which means they were “OMRI listed” as of June, 2019, when the materials were reviewed.

Accredited Organic Certifiers in New England

Connecticut:

See Massachusetts.

Massachusetts:

Don Franczyk (Main Office)
Baystate Organic Certifiers
1220 Cedarwood Circle
N. Dighton, MA 02764
email: dfranczyk@baystateorganic.org
Phone: (774) 872-5544
Fax: (774) 872-5545
<http://baystateorganic.org>

Maine:

Chris Grigsby
MOFGA Certification Services
294 Crosby Brook Rd.
P.O. Box 170
Unity, ME 04988
(207) 568-4142
email: certification@mofga.org
www.mofgacertification.org

New Hampshire:

Jennifer Gornnert, Director
New Hampshire Department of Agriculture
Division of Regulatory Services
25 Capitol St. P.O. Box 2042
Concord, NH 03302-2042
(603) 271-3685
email: Jennifer.Gornnert@agr.nh.gov
<https://www.agriculture.nh.gov/divisions/regulatory-services/organic.htm>

Rhode Island:

Matt Green
Div. of Ag.
235 Promenade St.
Providence, RI 02908
(401) 222-2781 x4509
email: matt.green@dem.ri.gov
<http://www.dem.ri.gov/programs/agriculture/orgcert.php>

Vermont:

Nicole Dehne
Vermont Organic Farmers, LLC
P.O. Box 697
Richmond, VT 05477
(802) 434-4122
email: nicole@nofavt.org

Vegetable Transplant Production

Vegetable transplants are commonly grown in New England greenhouses for field transplanting or spring sales at farm market stands. Many vegetable crops are grown from transplants in New England due to the late spring, short growing season and desire to obtain mature, harvestable crops as soon as possible.

Transplant production is a specialized part of vegetable production that requires a protected environment such as a greenhouse and careful attention to detail. Although vegetable bedding plants may only be in the greenhouse for a short period of time, it is important to produce high quality pest-free transplants. Scheduling, plant nutrition, greenhouse management, and pest management influence quality. Some vegetable producers choose to purchase transplants while others grow their own.

Transplant Production Resources

Aldrich, R. and Bartok, J. Greenhouse Engineering, <http://host31.spidergraphics.com/nra/doc/Fair%20Use%20Web%20PDFs/NRAES-3...>

Most recent version, New England Greenhouse Floriculture Guide: A Management Guide for Insects, Diseases, Weeds and Growth Regulators, available from: <https://www.negreenhouse.org/pest-guides.html>

Bartok, J. Greenhouses for Homeowners and Gardeners: PALS Publishing (Formerly NRAES), <http://host31.spidergraphics.com/nra/doc/Fair%20Use%20Web%20PDFs/NRAES-1...>

Biernbaum, John. 2006, updated 2013. Greenhouse Organic Transplant Production. Michigan State University: <https://www.canr.msu.edu/hrt/uploads/535/78622/Organic-Transplants-2013-13pgs.pdf>

Organic Greenhouse Vegetable Production, Potting Mixes for Certified Organic Production, Organic Greenhouse Tomato Production, Plug and Transplant Production for Organic Systems. (ATTRA) - National Sustainable Agriculture Information Service <https://attra.ncat.org/horticultural/#Greenhouse>

University of Conn Extension Greenhouse IPM Program: http://ipm.uconn.edu/pa_greenhouse/

University of Massachusetts Extension Greenhouse Crops and Floriculture Program: <https://ag.umass.edu/greenhouse-floriculture>

TYPES AND VARIETIES

For Field Production: Consult with your seed supplier and review the individual crop sections in the manual for suggested varieties that grow well in New England. Grow the crops at appropriate temperatures. Pay particular attention to scheduling times, light, temperature and nutritional requirements needed to grow healthy transplants.

With the exception of a few perennial vegetables, vegetable plants are started from seed. Brussels sprouts, broccoli, cabbage, lettuce and tomatoes are easy to transplant vegetables that are able to absorb water efficiently and form new roots rapidly. Vegetable plants that are a little more

difficult to transplant do not absorb water as efficiently, but form new roots quickly include celery, eggplant, onion and pepper. Vegetable plants that are difficult to transplant include cucumbers, melons, summer squash and sweet corn.

For Spring Bedding Plant Sales: There are so many choices, from gourmet greens and vegetable amaranth (popular in Southern Asia, Africa, and West Indies) to yellow cherry tomatoes and an assortment of colored peppers and eggplants. To find new varieties to grow for spring bedding plant sales, see the All American Selection (AAS) Winners website www.all-americanselections.org/, the National Garden Bureau website <https://ngb.org/> and your favorite seed supply company catalogues. State university trial results can also help you select varieties that will perform best in your area.

GROWING MEDIA AND NUTRITION

There are numerous factors affecting the growth of vegetable transplants including types of growing media, watering practices and fertilization programs.

Types of Growing Media

Growing media for vegetable transplants in greenhouses contain a variety of soilless ingredients such as peat moss, vermiculite, perlite, shredded coconut husks (coir), or composted materials plus starter nutrients and a wetting agent. Field soils are generally unsatisfactory for the production of plants in containers because soils do not provide the aeration, drainage and water holding capacity that are required. They also need to be pasteurized or fumigated to prevent the development of diseases and germination of weed seeds.

Premixed media is common in the greenhouse industry. Suppliers offer a diversity of mixes that are available prepacked (in bags, bales, super sacks) or in bulk. Growing media are designed to achieve high porosity and water retention while providing adequate aeration. Recipes are specially formulated for propagation, specific crops or general use. Soilless media purchased in bags do not have to be pasteurized or fumigated before use. Preventative applications of biological fungicides or fungicides may be necessary with vegetable transplants prone to damping off. Growers can also obtain commercially available mixes with different types of biological fungicides added to the mix. Those containing mycorrhizae, though increasingly common, may have been prepared many months in advance and may contain insignificant concentrations of living inoculum.

Compost-based mixes are also available commercially as a substitute for traditional soilless media, especially for organic production. See section below on organic vegetable bedding plant fertility.

Media Testing

Test your growing medium to adjust your fertilizer program and to manage the pH to prevent nutritional problems.

Samples from soilless mixes are tested differently than samples from field soil. Unlike field soil tests that extract nutrients with weak acid solutions, soilless media is mixed with distilled water at a standard dilution and then analyzed. There are three commonly used methods of testing soilless media using water as an extracting solution: saturated media extract (SME), 1:2 dilution method, and leachate Pour Thru. The values that represent each method of testing are different from each other. Likewise, values for specific nutrients are likely to differ with testing methods. Always use the interpretative data for the specific soil testing method used to avoid incorrect interpretation of the results. Most soil testing laboratories use the SME method. The 1:2 and Pour Thru are methods that can be used by growers on-site using portable soil testing meters. Since different soil testing labs may use different dilutions, it is not advisable to compare soil test results from one lab to those obtained from another. Use one laboratory for consistent results.

In addition to carrying out a complete soil test, growers should routinely check the electrical conductivity (EC) or soluble salts and pH of their growing media. These tests can be done on-site using portable testing meters, or samples can be sent to a university soil testing laboratory.

Taking a Sample: Take several samples at root depth from several containers and mix together in a clean container. Sampling several containers is important because a sample from one pot or flat could be an anomaly (values too high or too low) misrepresenting the crop as a whole. Sample about 2 hours after fertilizing or at least on the same day. If slow-release fertilizer pellets are present, carefully pick them out of the sample. If the pellets are left in, they can break during testing and this may result in an overestimation of fertility.

Be consistent in sampling procedures each time you sample. A lot of variability can be introduced to tests due to inconsistent sampling and this diminishes the value of testing especially if you are trying to track fertility levels.

Take about one cup of the medium and dry at room temperature. Put in a sandwich size zip-type bag and close it tightly. Identify each sample on the outside of the bag for your use.

pH: The term pH refers to a measurement of the hydrogen ion concentration (how acidic or basic a solution is). The pH can range from 0 (very acidic) to 14 (very basic). Growing medium pH drives the chemical reactions that determine whether nutrients are either available for root uptake (soluble) or unavailable for root uptake (insoluble). Major influences on the media pH include limestone in the growing media, irrigation water pH and alkalinity, and the acid/basic nature of fertilizer solution used. Also remember that smaller cells and plugs are subject to very rapid media pH change.

The optimum pH range for vegetable bedding plants grown in soilless media is 5.5-6.5.

Electrical Conductivity (EC) or Soluble Salts: Soluble salts are the total dissolved salts in the root substrate (medium) and are measured by electrical conductivity (EC). Most fertilizers (except urea) are salts and when placed in solution they conduct electricity. Measuring EC or soluble salts provides a general indication of nutrient deficiency or excess. A high EC reading generally results from too much fertilizer in relation to the plant's needs, but inadequate watering and

leaching or poor drainage are other causes. Sometimes high EC levels occur when root function is impaired by disease or physical damage. Always check the condition of the root system when sampling soil for testing.

Water Quality and Alkalinity: The quality of water used for irrigation and mixing fertilizers should be tested each year for pH, alkalinity and electrical conductivity. Water containing a large concentration of dissolved salts can cause high soluble salts damage.

Water alkalinity is a measure of the water's capacity to neutralize acids. An alkalinity test measures the level of bicarbonates, carbonates and hydroxides in water. Test results are generally expressed as ppm of calcium carbonate. Irrigation water tests should always include both pH and alkalinity. A pH test itself is not an indication of alkalinity. Water with high alkalinity (i.e., high levels of bicarbonates or carbonates) always has a pH value of 7 or above, but water with high pH does not always have high alkalinity. This is important because high alkalinity exerts the most significant effects on growing medium fertility and plant nutrition.

Water with high alkalinity (>150ppm CaCO₃ of alkalinity) can result in iron deficiency chlorosis caused by increased root medium pH over time. This is usually influenced by the water source. Water with low alkalinity will have little ability to neutralize acidity. It is advisable to have your water tested prior to the spring growing season. High alkalinity can be reduced by injecting acid into the irrigation water. While most greenhouses use sulfuric acid, citric acid is approved for certified organic production. Calculate the amount of acidification required using the UMass Greenhouse Crops and Floriculture Program page: <https://ag.umass.edu/greenhouse-floriculture/fact-sheets/adjusting-alkalinity-with-acids>.

Fertilizers and Media pH

Most water-soluble fertilizers will change the potting media pH to some extent. Ammonium and urea-containing fertilizers lower media pH; nitrate fertilizers raise it. Potential acidity or basicity is printed on the fertilizer label based on pounds of calcium carbonate per ton of fertilizer. For example, if a 20-10-20 has a potential acidity of 429 pounds per ton, then the reaction produced by one ton of fertilizer will neutralize 429 pounds of calcium carbonate. If 15-0-15 has a potential basicity of 420 pounds per ton, then the reaction produced by one ton of the fertilizer will be equivalent to 420 pounds of calcium carbonate. Changes in pH of the media are caused by plant responses to the forms of nitrogen. Because fertilizers can be used to manipulate the pH of the growing media, most growers alternate fertilizers to balance the pH of the growing medium.

Fertilizer Injectors: In conventional greenhouses, nutrients are delivered using various water-soluble fertilizers through a fertilizer injector, through the use of controlled-release fertilizers, or using a combination of these two methods.

Fertilizer injectors are used in liquid feeding systems. These devices inject a small quantity of concentrated fertilizer solution (stock solution) into the irrigation line so that the water leaving the hose (dilute solution) supplies the proper concentration of fertilizer. When used at every watering, this is known as "constant feed." Rates of fertilization are often

given in parts per million (ppm) of nitrogen, which is a way of expressing the fertilizer concentration. The amount of fertilizer to dissolve per gallon of water (stock solution) to make the appropriate concentrate for a specific injector setting needs to be determined. This information is listed on the bag of fertilizer. An injector setting of 1:100 indicates that 1 gallon of fertilizer concentrate delivers 100 gallons of final solution and is not an indication that the injector is delivering 100 ppm.

Choosing Fertilizers: Factors to consider when choosing fertilizers include the ratio of ammonium to nitrate-N, trace element starter charge, content of calcium and magnesium, and potential acidity or basicity. There are many fertilizers available to use for vegetable bedding plant production. Commonly used fertilizers include 15-0-15 (Dark Weather Feed), 15-16-17 and 20-10-20, 15-5-15 (“Cal-Mag”), and 13-2-13.

Plug Production (15-5-15, 13-2-13). Both fertilizers combine high nitrate, low phosphate with extra calcium and magnesium, plus micronutrients. 15-5-15 is a little less basic (raises pH) than 13-2-13 and contains less nitrate and a little more phosphorus. Both are commonly used for plug production.

Peat-Lite Specials (15-16-17, 20-10-20, 21-5-20). These fertilizers are among the most popular for routine fertilization of vegetable bedding plants. All are high (>50%) nitrate fertilizers. However, these fertilizers also have elevated trace element levels which may raise iron (Fe) and manganese (Mn) to toxic levels at low pH. All are acid-forming fertilizers, but 20-10-20 has the greater potential acidity.

General Purpose (17-5-17, 17-3-17, 17-4-17). All are high (>50%) nitrate fertilizers with calcium, magnesium and other minor elements. All produce a nearly neutral reaction.

General Purpose (20-20-20). Growers who use this fertilizer with soilless media risk ammonium toxicity because the nitrogen in this fertilizer is 75% ammonium and urea. Some growers who use media containing soil do not appear to have problems. If 20-20-20 is used, the soilless growing medium should be tested frequently for ammonium. 20-20-20 supplies trace elements and has the greatest potential acidity of fertilizers commonly used in New England greenhouses. Tomato, eggplant and pepper plants are especially sensitive to ammonium, reducing plant growth and causing yellowing of the foliage.

Low Phosphorus (P) Fertilizers (20-0-20, 20-1-20, 15-0-15). These fertilizers can be tried as an alternative to chemical growth regulators for vegetable transplants. This technique of growth control is sometimes called “phosphorus starvation.” It is generally believed that more P than necessary is being applied to greenhouse crops. Too much P may cause plants to stretch and P is a ground water pollutant. Unfortunately, in terms of height control, these fertilizers may be of no benefit if they are applied to a growth medium containing superphosphate or a high starter charge of P. Also, there is a risk of P deficiency if the fertilizers are used continuously with low P growth media. The low P fertilizers are quite different in many ways. 15-0-15 and 20-0-20 supply Calcium (Ca). 15-0-15 is a basic (raises pH) fertilizer containing about 95% nitrate and 20-0-20 is a neutral fertilizer and is 50% nitrate. 20-1-20 is an acidic fertilizer and it does not supply Ca, but it is about 70% nitrate.

Calcium Nitrate and Potassium Nitrate (15-0-15). High nitrate, high calcium fertilizer. Some growers alternate its use with the Peat-Lite Specials on a 2-3 week basis to supply Ca and to counter the acidic effect of the Peat-Lite fertilizers. If water-soluble NPK fertilizer is not applied at least once every 10 to 14 days, superphosphate must be incorporated into the growing medium.

Rates and Frequency of Fertilizing

Small, slow-growing plants should receive lower rates or less frequent application until they are well-established. Care should be taken not to over-fertilize vegetable bedding plants to avoid overgrown plants. Young seedlings are especially vulnerable to injury from high soluble salts.

While plants are in the plug or seedling stage, use a complete water-soluble fertilizer at 50-100 ppm N every time plants are watered and use clear water (no fertilizer) every third watering. Use the lower rate (50 ppm) early and the higher rate (100 ppm) later if the seedlings are to be held in the flat or tray three or more weeks before transplanting. Shortly after transplanting, as plants approach rapid growth, increase the rate to 200 ppm N at every watering or 300 ppm N once every 7 days, watering with clear water 2-3 times between each fertilization.

Fertilizer Solution Volume: The volume of fertilizer solution applied has a dramatic effect on the growth of the vegetable bedding plants. As the volume of water-soluble fertilizer increases, the quantity of nutrients delivered to the plant also increases resulting in an increase in height, stem diameter and plant weight. Doubling the volume applied also doubles the amount of each nutrient potentially available to the plant.

Plant Growth Rate and Environmental Conditions. In general, nutrient requirements of vegetable bedding plants are greatest during periods of rapid growth. Too much fertilizer during slow growth periods may lead to high soluble salts; failure to provide enough fertilizer during periods of rapid growth will lead to nutrient deficiency.

Nutritional Problems

Early in production serious nutritional problems include: high soluble salts, trace element toxicities, and ammonium toxicity. Late in production, particularly in cell packs, plants may develop nitrogen deficiency symptoms as the earliest indication of insufficient fertility levels.

Soluble Salts. Injury to vegetable bedding plants from excess salts seems to be most common shortly after transplanting. Seedlings are much less tolerant to excess salts than established, rapidly growing plants. Some soilless mixes may contain enough “starter charge” to cause excess salts problems in the first few weeks after transplanting, particularly when a water-soluble fertilizer is also applied. Excessive drying, poor drainage, and uneven watering are factors that can aggravate this problem. Check roots of plants often and conduct regular soil tests to identify and prevent problems. It is difficult to diagnose a soluble salts problem by symptoms alone. Often nutrient deficiencies and root diseases cause the same symptoms, along with inadequate watering. A soil media test is advisable if you suspect salt injury.

Trace Element Toxicities. Iron (Fe) and/or manganese (Mn) can be accumulated to toxic levels by tomato plants. Symptoms appear as numerous small dark spots and mottling of the foliage. The potential sources of excess Fe and Mn are: trace element fertilizers in the mix, water-soluble fertilizers with elevated trace elements levels, and sometimes irrigation water. Low growth medium pH aggravates the problem by increasing Fe and Mn availability. Toxicity can be avoided by keeping the pH in the range of 5.8-6.0 for susceptible crops and by the use of fertilizers with lower trace element levels.

Ammonium Toxicity. Tomato, eggplant, and pepper are most sensitive to ammonium nitrogen, but many other vegetable bedding plants can be harmed if ammonium becomes excessive. During the early spring (February or March) with low light and cool media conditions, plant growth may be reduced with yellowing of the foliage. To prevent ammonium toxicity, use water-soluble fertilizers that supply about 50/50 ammonium/nitrate to fertilize plants in soilless media.

Nitrogen and Phosphorus in Transplant Production. Nitrogen concentration in the greenhouse fertilizer program has a greater effect on the growth of transplants in the greenhouse than either phosphorus or potassium. Raising the level of nitrogen results in taller transplants with thicker stem diameters and heavier plant weights, but applying too much nitrogen may result in soft, poor quality transplants. These lush transplants may also be more prone to phloem feeding insects such as aphids, whiteflies and to foliar blights. Phosphorus has a limited effect on the growth of transplants when compared to nitrogen, but should be included as part of a complete fertilizer. Increasing the phosphorus concentration results in a moderate increase in transplant height, stem diameter, and shoot fresh and dry weight. If phosphorus is restricted to the point at which the plants show extreme phosphorus deficiency (purple leaves and stems, stunted plants), field performance will be reduced.

Organic Vegetable Bedding Plant Fertility

Conventional growing media containing synthetic ingredients (wetting agent, starter chemical fertilizer) cannot be used in organic production of field transplants and vegetable bedding plants. However, acceptable growing media can be created from a wide variety of approved materials. These blends for organic production may be purchased off-the-shelf, custom-blended by manufacturers, or produced on-the-farm.

Purchasing a commercially prepared mix for organic production is the easiest way to get started and most growers choose this option to ensure consistency and reduce the risk of soil-borne diseases. Common components such as peat moss, perlite, vermiculite, and coconut coir are acceptable for organic certification. Compost, being the most renewable, is the preferred material for many organic growers. Commercial mixes for organic production may contain a “starter charge” of organic fertilizer or no starter fertilizer at all. Check with your organic certifier to make sure your mix complies with standards. More information on growing media for organic production can be found in the ATTRA publication, “Potting Mixes for Certified Organic Production”.

Supplementing pre-plant fertilizers or compost with liquid organic fertilizers is generally required to provide adequate

nutrition. Fish fertilizers, made from waste products of the ocean fish processing industry, are thick, heavy liquids which are difficult to use with fertilizer injectors because the concentrate consists of very fine particles in suspension. Dilute solutions develop a strong odor in storage. Because of this, fertilization may need to be less frequent. Application rate will depend on frequency. However, excessive fish fertilizer builds up a nutrient rich scum on the surface of media, leading to algal growth and shore fly proliferation.

Different fish fertilizers supply plant nutrients at varying levels of availability. Some may be stabilized with phosphoric acid, resulting in a high concentration of readily available phosphorus. Others contain liquid seaweed resulting in a small addition of potassium. Most fish fertilizers contain ammonium nitrogen, which as discussed previously, can be a problem for sensitive transplants such as tomatoes, peppers and eggplants. In New England, the Neptune’s Harvest Brand is the most commonly available fish fertilizer and it is OMRI-approved for organic production.

Some growers use Nature’s Source Professional Plant Food 10-4-3 a liquid, “organically-based” fertilizer. The organic portion is oilseed extract. Most of the nutrients, however, are derived from inorganic salts and for this reason it cannot be used for certified organic production.

Several liquid fertilizers used for organic production are derived from plant extracts. The best-known of these has been Nature’s Source Organic Plant Food 3-1-1, in which the nutrients are derived from “oilseed extract”. The container has dilution rates expressed in familiar terms for greenhouse growers and has been recommended based on trials at the University of Massachusetts.

Several other liquid organic products are available, such as Biolink 3-3-3 (also an oilseed extract), Converted Organics 3-2-1 (a byproduct of grain fermentation), 1-1-1 Liquid Compost Concentrate and Verdanta PL-2, 2-0-6 (a liquid made from fermented sugar cane and sugar beet molasses). Verdanta would be used as a supplement to use in combination with other fertilizers used for organic production that are low in N or K.

Verdanta EcoVita 7-5-10 (granular) is composed of bone meal, soybean meal, cocoa shell meal, feather meal and fermented sugar cane and sugar beet molasses.

Mixing and application. The fish fertilizers and plant extract fertilizers are sold as concentrates and they must be diluted in water to be safe for plants. Nature’s Source, Bombardier, and Espartan have a pleasant “beer-like” aroma as concentrates, but within 7 days of being mixed with water they “spoil” and develop unpleasant odors. The nutrient value of spoiled fertilizer is unknown and the colonies of bacteria that develop may plug irrigation lines, so diluted fertilizer solution should be used as soon as possible after mixing.

Fish fertilizer has the thickest and least consistent solution and should be agitated before mixing with water. Bombardier and Espartan concentrates are “syrupey” but mix well with water. Nature’s Source is the thinnest concentrate and it mixes well with water and can pass through fertilizer injectors.

Sustane 8-4-4 and EcoVita are granular fertilizers mixed with the growing medium before planting. These are the

easiest organic nutrient source to use in combination with the liquid types.

Fertilizer analysis. Some fertilizers used for organic production supply only one or two of the NPK elements; an example is Bombardier which is 8-0-0. A grower using Bombardier would have to use other fertilizer(s) to supply P and K. One possibility would be Sustane with an 8-4-4 analysis or some other complete NPK granular organic fertilizer.

Nutrient disorders. Plants may develop an overall light green or yellowed color caused by a general nutrient deficiency or more likely, N deficiency. For example, if Sustane is used alone, the symptoms might occur about 45 days after planting, the end of its release time. This can be prevented by applying an organic liquid fertilizer supplement about 30 days after planting.

Interveinal chlorosis sometimes occurs about halfway through cropping time if plants are only fertilized with some liquid organic fertilizer starting at planting. This chlorosis is most likely caused by an accumulation of too much ammonium-nitrogen in the plant, so-called “ammonium toxicity.” Most greenhouse crops do best with a combination of ammonium and nitrate nitrogen. Unfortunately, fertilizers used for organic production generally don’t contain nitrate-nitrogen. The best approach is to rely on Sustane as the sole source of nutrients for the first month after planting and then start applying Nature’s Source or another liquid organic fertilizer.

Use fertilizers for organic production with caution, on plants you know have exacting nutrient requirements or those prone to foliar chlorosis. Fertilizers should always be tried first on a small number of plants.

Transplant Fertilizer Resources

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Cox D. 2014. *Organic Fertilizers - Thoughts on Using Liquid Organic Fertilizers for Greenhouse Plants*. Sept.-Oct. Floral Notes 27(2) <https://ag.umass.edu/sites/ag.umass.edu/files/newsletters/14fnseptoct272.pdf>

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SEEDING AND TRANSPLANTING

Handling Growing Media

How soilless growing media is handled can greatly influence the air space and available water for plant roots. The major goal is to preserve the air space or porosity to insure healthy root growth.

Add water to peat-based mixes before filling plug trays to help create more aeration. Satisfactory filling moisture is achieved if the slightest bit of visible water appears when squeezed between the fingers. Most growers work with a moisture content of 45%-55% by weight. If mixing your own media, thoroughly mix components, but do not over-mix, which will cause particle size to decrease. Over processed media quickly loses porosity, resulting in stunted transplants.

To prevent compaction that encourages damping-off diseases and poor root growth, lightly fill containers, including plug trays, and brush the excess media off the top. Once filled, avoid nesting or stacking trays on top of one another. Stacking containers causes compacted media and reduced air space. This damage cannot be remedied after creating this compaction. Try to stagger trays.

When dibbling seed trays, try to avoid compressing the mix; gently press to ensure a small indentation for seeds.

Production Schedules

Starting seeds too soon will result in overgrown transplants of poor quality. An excessively warm greenhouse will cause rapid, spindly growth. The following are guidelines for growing vegetable bedding plants. Note the number of weeks from seed to sale or transplant. This will vary according to different growing conditions and should serve only as a guide.

Germination Tips for Selected Crops

Warm temperatures and uniform moisture are needed to ensure successful germination and get the plants off to an even start. Many germination chamber systems are commercially available including custom built germination units. Growers often use bottom heat or root zone heating to provide warm, even temperatures. Rubber tubing or mats with hot water are placed on the bench top under the plants. A weed mat barrier is placed on the top of the bench to help spread the heat with skirts on the side to help contain the heat. It is important to remove flats from the germination chamber as soon as radicles break through the seed coat to prevent seedling stretching. Experience and experimentation with your total seeding system is the key to uniformity and success.

Celery

Celery seeds germinate best at 70°F with continuous light. To prevent bolting, maintain greenhouse temperatures above 55°F.

Cole Crops

To prevent premature seeding or bolting, avoid temperatures below 50°F. The cold temperatures cause the development of premature heads or “buttoning” in cauliflower and broccoli. Any stress or check in growth results in a “wirestem” and plants will not become well established in the field resulting in reduced yields and performance.

Eggplant

Eggplant seed can be directly sowed into 50 cell trays to shorten the time needed to produce transplants by approximately one week. Eggplants are susceptible to chilling injury and should not be grown below 40°F. Any stress or check in growth will result in tough woody stems

and transplants that will have a tough time getting started later in the field or garden.

Tomatoes

Exposure of tomato plants to temperature below 60°F will likely result in rough fruit (catfacing) on the first few clusters. Transplant young seedlings into 2"-3" containers when they have two true leaves and grow on until planted in the field. For earliest production, some growers finish their transplants into 6" or larger containers.

Peppers

Germination is very slow at lower temperatures. Seedlings develop well at 75°F day and 65°F night temperatures. Seeds may be directly sown into 72-cell trays for early production. Peppers are prone to damping off diseases especially if the media is compacted. Jalapeno pepper varieties may require much more time in the greenhouse than bell peppers to achieve adequately size plants.

Cucurbit Crops

Cucurbits do not transplant well, and are best sown in the final container. After germination, excess plants can be thinned. Cucurbit transplants should be field set with a maximum of two true leaves and before plants get leggy when exposed to high daytime temperatures.

Transplants

Transplants can be grown in all types and sizes of containers. Seeds are sown in open seed flats or in single-cell (plug) trays. Before sowing, decide whether germination and finishing will occur in the same container or whether seeds will be sown in one container followed by transplanting to a finishing container.

Germinating and growing small plugs requires more attention to detail and is probably best done by local, specialty propagators. Trays for transplants vary in size from 32 cells to 500 cells. The number of plants in a tray depends on the cell size needed for each plant. Large cell sizes such as 32, 50 or 72 are often used for vine crops and early harvests. Plants are less stressed in larger cells if it is necessary to hold plants for several days before transplanting in the field. Mid-size cell sizes such as 72 and 128 are suitable for tomatoes, peppers, eggplant, and Cole crops. Small cells such as 128, 200 or 288 may be used for crops such as lettuce or onions. Before making a decision, consider your available labor, amount of greenhouse space, and the cost and benefit of each production method. Plug seedlings should be transplanted as soon as possible after they have reached finished size.

Some growers will produce their vegetable transplants for sale to home gardeners in biodegradable pots such as coconut husk fiber (coir) pots, fiber or jiffy peat pots or composted manure (Cowpots) pots or 80% wood fiber, 20% peat (Fertil) pots. Cowpots and Fertil pots are OMRI listed.

Purchased plugs: Purchase transplants from a reputable local supplier to minimize the potential of importing severe disease and insect problems that are common in other regions of the country. Open and unpack the boxes immediately upon arrival and check the physical condition of the plants. Inspect plants for root and foliar diseases and for insects and mites. Report any damage or discrepancies immediately to your supplier (most companies want to hear within 24 hours). Photographs are also helpful.

Place plant trays on benches and water thoroughly with plain water (no fertilizer); be sure that plugs on the edges of

Table 17: Germination and Growth of Vegetable Transplants

Crop	Germination Temperature* (°F)	Optimum Day Production Temperature** (°F)	Minimum Night Temperature** (°F)	Approx. No. Weeks to Sale**	Approx. No. Weeks to Transplant in Field*
Basil	70***	65–70***	62–65***	5–7	4–6
Broccoli	70–85	65–70	55–60	5–7	5–7
Cabbage	70–85	65–70	55–60	5–7	5–7
Cantelope	75–90	75–80	60–70	2–3	4–5
Cauliflower	70–75	65–70	55–60	5–7	5–6
Celery	70	65–70	55–60	8–10	5–7
Cucumber	90	75–80	60–70	2–3	2–3
Eggplant	70–85	70–75	60–65	6–8	5–7
Lettuce	65–75	65–70	55–60	5–7	4
Onions	75	65–70	55–60	6–8	10–12
Peppers	85	70–75	60–65	6–8	5–7
Tomatoes	85	70–75	60–65	5–7	5–7
Watermelon	90	75–80	60–70	2–3	3–4

* Maynard D.N. and G.J. Hochmuth. 2007. Knott's Handbook for Vegetable Growers. Fifth Edition

**Tips on Growing Bedding Plants, Ohio Florists Association, 1987 and 1999 Editions.

***2017 Seed Product Information Guide. Ball Seed, PanAmerican Seed, Kieft Seed. http://www.ballseed.com/PDF/15539_PIG_ENG_BSC_LR.pdf

Note: The greater the difference between daytime and nighttime temperatures, the more stems will elongate. See Managing Plant Height.

the trays are thoroughly watered. Plugs can dry out quickly due to the small volume of growing medium; check the trays 2 or 3 times daily for watering. After the initial watering, apply a general-purpose fertilizer (such as 20-10-20) at 50-60 ppm of nitrogen at every other watering. Allow plants to acclimate to the greenhouse conditions for 24 to 48 hours before transplanting.

Transplanting to a finishing container: Water the plug trays thoroughly 2 to 3 hours before transplanting; this aids in removing the plugs from the trays. Prepare your cell packs or pots by filling them with pre-moistened growing medium and pre-dibbled holes for the plugs. Lightly fill containers and brush off excess. To prevent compaction, do not pack down or stack (“nest”) filled flats.

Take special care during transplanting to handle plants gently and avoid planting too deeply. Stems of tender seedlings can be easily injured when workers grasp or “pinch” the stems too tightly. This often leads to stem cankers causing plants to wilt and die. Plant plugs at the same depth as the original plug. Some transplants may have elongated stems and it is tempting to bury the stem. Resist the temptation, except for more adaptable tomato plants.

See information under the specific crops for additional information on transplant production and planting.

PLANT CULTURE AND HEIGHT MANAGEMENT

Special Note about Unvented Heaters in Greenhouses

One of the most critical features in greenhouses is a source of heat to provide appropriate temperatures. A frequent question by growers is the use of supplemental heaters in the spring. Do not use unvented heaters when growing transplants in the greenhouse or high tunnel. An unvented heater is one that is designed without a flue connection so that the heat and products of combustion are exhausted into the greenhouse. Unvented heaters can be fired with natural gas, propane or kerosene which all contain traces of sulfur. During combustion sulfur in the fuel is combined with oxygen to form sulfur dioxide. Levels as low as 0.5 part per million (ppm) can cause injury to some plants. Once the sulfur dioxide enters the plant through the stomates, it reacts with water to produce sulfuric acid that causes leaf burn, flecking and general chlorosis. Tomatoes and white petunias are very sensitive and will show damage in as little as one hour. Ethylene gas is another pollutant formed during combustion. Ethylene levels as low as 0.01 ppm can cause symptoms such as malformed leaves and flowers, stunted growth, bud abscission, epinasty (downward bending of leaves) and flower senescence.

Watering

Handwatering and overhead irrigation systems are the primary methods of watering vegetable transplants. The amount of water and frequency of watering will vary depending on container size, growing media, greenhouse ventilation and weather conditions. Water requirements change as plants grow. The weight of containers is commonly used to determine the moisture level of the media and when to water. Pick up individual containers and if they feel heavy, even though the surface is dry, do not water. If containers

are light in weight, even though the surface looks wet, investigate further to make sure the water is thoroughly wetting the media. Tempered water is used by some growers to minimize shocking seedlings with cold irrigation water.

Some growers successfully use a water gauge that measures how much water is used. Some growers use a container placed among the pots to measure the amount of water applied. Experience will dictate how much water is needed to thoroughly saturate a container. Other growers use their finger to feel the media in shallow containers (the surface can be dry, while deep in the pot the media can feel wet).

It is important to water thoroughly, to moisten the entire container, which will promote root growth to the bottom of the container. If this is not done, root growth will develop in the upper part of the container and plants will be more prone to drying and drought stress. Excessive watering leads to succulent plants and restricted root growth.

Allow plants to dry down before watering, but do not let the plant wilt severely, as this will damage roots. Vegetable transplants should be watered thoroughly early in the day to allow foliage to dry before evening. If foliage remains wet overnight, foliar diseases will develop.

Most commercial mixes contain a wetting agent that provides initial hydration and improves wettability of the mix. Older mixes (stored longer than 8 months) are harder to wet and the addition of a liquid wetting agent may be needed.

Managing Plant Height

Compact, uniform transplants can be easily handled for planting in the field. Leggy transplants may develop with low light levels, overwatering, overfertilizing or when plants are held for longer than anticipated in the greenhouse due to unseasonable weather conditions. Since very few growth regulators are registered for vegetable transplants, plant height is often managed by increasing light levels, using mechanical stresses such as “brushing” and adjusting temperature, water and fertilizer levels.

Maximizing Light Levels: Maximizing the amount of light plants receive helps reduce plant stretch. Giving plants adequate space, and replacing plastic coverings as needed helps prevent reduction in light levels.

Adjusting Temperature (DIF): The greater the difference between daytime and nighttime temperatures, the more plants will “stretch” (stems elongate). When the day temperature is very warm and the night temperature is cool or cold, plants will be taller. If the day and night temperatures are both the same, plants will be shorter than with warm days and cool nights. If the night temperature in the greenhouse is kept warmer than the day temperature by using heating at night and ventilation during the day, the plants will be even shorter. Keeping day temperatures cool (70° F) will help keep transplants shorter. The relationship is referred to as DIF, or difference between day minus night temperatures. The critical period during a day for height control using DIF is the first 2-3 hours following sunrise, starting about 30 minutes before sunrise. By lowering the temperature during this 3-hour period by a few degrees, plant height in many vegetables can be managed. Vegetables vary in their response to DIF. For example, tomatoes, cole crops, eggplant and melons are very responsive, while squash, cucumber and peppers are much less responsive.

Mechanical Brushing: Mechanical stress reduces stem elongation. Wind, shaking or brushing are all types of mechanical stress. Research has shown that mechanical stress reduces stem elongation and maintains plant height. For example, brushing transplants twice daily for 18 days using about 40 strokes back and forth with a cardboard tube suspended from an irrigation boom can result in as much as a 30% reduction in stem elongation. Growers have also successfully used a wand made of plastic plumbing pipe or a flat piece of polystyrene foam. Vegetable plants such as tomatoes, eggplants, cucumbers and some varieties of broccoli and cabbage have responded to this method of height control. Note that this technique has damaged some tender plant species such as peppers and could also enhance the spread of disease. Brush plants when the foliage is dry and if you see plant damage, reduce the number of times you are brushing the plants. Brushing can improve establishment of transplants in the field. They resume their normal growth about 3 days after the brushing stops. There is also little or no reported effect on yield.

Water Stress: Water stress is another tool growers can use to manage plant height. Maintaining plants on the dry side limits cell expansion and plant growth. This method requires close monitoring to avoid permanent damage such as leaf burn or even plant death. One technique is to irrigate the growing mix thoroughly and then allow it to dry to the point where plants wilt before irrigating thoroughly again. Growth is restricted during the period when the growing medium is very dry. Once watered, the plants rapidly resume growth. Experienced tomato growers have successfully used this technique.

Low Phosphorus: Withholding nutrients can also be used to prevent stretching. Low phosphorus fertilization is especially effective for tomatoes. If carefully managed, a mild to moderate phosphorus (P) deficiency may result in a desirable reduction in growth with no foliar symptoms of P deficiency. If this method is used, use a starter fertilizer when transplanting into the field. *NOTE: To produce healthy transplants for field production, water and nutrients must be carefully managed.*

Plant Growth Regulator: A review of pesticide labels indicates that Sumagic (uniconazole) is the only growth regulator labeled for use on a limited group of vegetable transplants (tomato, pepper, eggplant, tomatillo, ground cherry, and pepino). Sumagic is a gibberlin biosynthesis inhibitor suppressing plant height by inhibiting internode elongation. It is a particularly active plant growth regulator, so very small concentrations are needed. Apply Sumagic only as a foliar spray at a rate of 2-10 ppm. As with any plant growth regulator, it is recommended to test growth regulator treatments on a small number of plants with a low rate before full-scale implementation. The maximum cumulative amount of Sumagic applied must not exceed 10 ppm with coverage of 2 quarts per 100 sq. feet. This means that total amount used in sequential applications can only add up to 10 ppm spray (example, two applications at 5 ppm or 4 applications at 2.5 ppm). The last spray must be no later than two weeks after the two to four leaf stage of development. Experiments have shown that sequential applications produce the best results and that the earlier that the plants receive the Sumagic spray, the greater effect it will have on the final height of the transplants. As only a limited

number of tomato varieties have been tested, growers are encouraged to do their own in-house trials on a small number of plants with a low rate before full-scale implementation.

Acclimating or Hardening-Off Transplants

The transition from the greenhouse to the field involves changes in light, temperature and wind. Vegetable transplants benefit by a gradual acclimating “hardening off” period before they are transplanted into the field. Gradual exposure to outdoor growing conditions and reduced watering at the end of the growing period with some protection from wind and temperature but full exposure to light can increase the survival rate of transplants in the field. Three to six days are adequate to acclimate transplants. Larger growers may be using roll out benches but smaller growers can use wagons to move transplants into and out of the greenhouses as needed.

Care must be taken to not “over-harden” young transplants. Cool-season crops exposed to very low temperatures can result in bolting (in cabbage) or buttoning (in broccoli or cauliflower). Warm-season crops generally are hardened at temperatures higher than those of cool-season crops. Cold temperatures can set back warm-season crops and can induce disorders such as catfacing in tomatoes.

TRANSPLANT DISEASE MANAGEMENT

There are a limited number of fungicides labeled for greenhouse-grown vegetable bedding plants compared to ornamental bedding plants. Integrated pest management (IPM) offers a practical way to effectively manage pests on vegetable bedding plants and transplants. Through the use of sound cultural practices, monitoring techniques, accurate problem identification, and timely implementation and evaluation of appropriate management strategies, growers can improve their production while minimizing their reliance on routine pesticide applications. IPM utilizes many different management options; genetic, cultural, physical, mechanical, biological and chemical. Routine crop inspection alerts growers to developing pest and cultural problems while they are still minor and can be easily managed. Early detection and intervention is the foundation of an IPM program. Use Table 18 to learn scouting practices for insect and disease pests which have effective biological control options.

Diseases of vegetable bedding plants include Botrytis blight, damping-off, Alternaria blight, late blight, powdery mildew, downy mildew, bacterial diseases such as bacterial leaf spot, bacterial canker, and black rot, and viral diseases such as Cucumber Mosaic Virus (CMV), Tobacco Mosaic Virus (TMV), and Tosopoviruses. Effective control of diseases requires accurate identification. Failure of disease control is often because the cause was not accurately identified. Symptoms caused by poor cultural practices can also mimic disease symptoms. Fungicides cannot correct problems caused by high soluble salts, poor aeration or a nutrient imbalance. An integrated approach to disease management involves the use of resistant cultivars, sanitation, sound cultural practices and the proper use of the correct pesticide.

Resistant Cultivars

Seed catalogues often feature disease resistant and tolerant varieties of vegetables. Utilize resistant varieties where feasible,

Table 18: Scouting and Biological Control Guidelines for Vegetable Transplants			
Pest	How to Monitor	Where to Look	Biological Control Options
APHIDS	Monitor weekly. Rely on plant inspection, not sticky cards. Look for small, 1/16" long aphids with two cornicles or "tailpipes" at the rear of the body. Identification to species is needed to determine which host specific aphid parasite to release when using biological controls. If uncertain, mixes of different species are available.	Underside of leaves and along stems on tips of new growth (especially on leaves above any honeydew-covered leaves) of eggplant, pepper, tomatoes and many different leafy vegetables. Signs of aphid activity: shed white skins, shiny honeydew, presence of ants, curled new leaves, and distorted growth.	<i>Adalia bipunctata</i> (predatory lady beetle); <i>Aphelinus abdominalis</i> (aphid parasite); <i>Aphidoletes aphidimyza</i> (aphid midge, predator); <i>Aphidius colemani</i> (aphid parasite); <i>Aphidius ervi</i> (aphid parasite); <i>Aphidius matricariae</i> (aphid parasite); <i>Chrysoperla</i> spp. (green lacewing, predator); <i>Hippodamia convergens</i> (predatory ladybeetle); Aphid Banker Plants (starter)
BACTERIAL LEAF SPOT	On peppers, at first, chocolate-brown spots are less than 1/4" in diameter, and water-soaked in appearance. Severely spotted leaves appear scorched and defoliation may occur. Some strains also cause leaf spot on tomatoes.	Seed-borne disease. More prevalent during moderately high temperatures, long periods of high humidity and leaf wetness.	
BOTRYTIS BLIGHT	Look for leaf blight and tan stem cankers. Botrytis blight produces characteristic gray fuzzy-appearing spores on the surface of infected tissues during humid conditions.	In areas where plants are spaced close together and with leaf wetness and condensation dripping from plastic greenhouse coverings.	
BROAD MITES	Look for symptoms of damage: leaf edges curling downward, twisted and distorted growth. With a 20x hand lens, or under a dissecting microscope, look on underside of leaves, especially on newest growth, for broad mites and their distinctive eggs.	Near ornamental crops affected with broad mites. Near whiteflies (broad mites may hitch a ride on whiteflies). Peppers are especially susceptible.	Biological fungicides: <i>Bacillus amyloliquefaciens</i> ; <i>Bacillus subtilis</i> ; <i>Glucoladium catenulatum</i> ; <i>Reynoutria sachalinensis</i> extract; <i>Streptomyces griseoviridis</i> ; <i>Streptomyces lydicus</i> ; <i>Uloocadium oudemansii</i>
CATERPILLARS	Inspect plants when adult moths are active, especially near Cole crops. Look for caterpillars, their feeding damage and frass.	Near ornamental crops affected with cyclamen mites.	<i>Amblyseius swirskii</i> (predatory mites); <i>Neoseiulus (Amblyseius) californicus</i> (predatory mites); <i>Neoseiulus (Amblyseius) cucumeris</i> (predatory mites).
CYCLAMEN MITES	Look for symptoms of damage: inward curling of leaves, puckering and crinkling. With a 20x hand lens or under a microscope, look within buds for mites and their eggs.	Near ornamental crops affected with cyclamen mites.	<i>Amblyseius swirskii</i> (predatory mites); <i>Neoseiulus (Amblyseius) californicus</i> (predatory mites); <i>Neoseiulus (Amblyseius) cucumeris</i> (predatory mites).
DAMPING OFF (Pythium root and stem rot)	Monitor seed flats of susceptible plants. Inspect weekly. Visually examine roots for cortex that sloughs off leaving central core.	Inspect plants weekly for signs of disease: wilted, stunted, off-color plants with discolored root systems. Focus on areas where plants stay wet, or where there may be high populations of shore flies that may carry disease spores. High soluble salts/fertility increases susceptibility.	Biological fungicides: <i>Bacillus amyloliquefaciens</i> ; <i>Bacillus subtilis</i> ; <i>Glucoladium catenulatum</i> ; <i>Reynoutria sachalinensis</i> extract; <i>Streptomyces griseoviridis</i> ; <i>Streptomyces lydicus</i> ; <i>Trichoderma aporellum</i> & <i>T. gamsii</i> ; <i>Trichoderma harzianum</i> ; <i>T. harzianum</i> & <i>T. virens</i>
DAMPING OFF (Rhizoctonia root and crown rot)	Monitor seed flats of susceptible plants including Cole crops, peppers, and tomatoes. Look for small, water-soaked spots on stems or leaves before seedlings collapse.	Seed flats near walkways or near dust and debris. Overcrowded seedling flats are more susceptible to damping off.	Biological fungicides: <i>Bacillus amyloliquefaciens</i> ; <i>Bacillus subtilis</i> ; <i>Glucoladium catenulatum</i> ; <i>Reynoutria sachalinensis</i> extract; <i>Streptomyces griseoviridis</i> ; <i>Streptomyces lydicus</i> ; <i>Trichoderma aporellum</i> & <i>T. gamsii</i> ; <i>Trichoderma harzianum</i> ; <i>Trichoderma harzianum</i> and <i>T. virens</i>
FUNGUS GNATS	Use sticky cards to monitor for adults. Place cards horizontally above soil surface. Potato chunks can be used to monitor for larvae. Check every two days.	Favorable habitats include areas with standing pools of water, mud floors, spilled media, and weeds.	<i>Bacillus thuringiensis</i> subsp. <i>israelensis</i> (pathogen); <i>Dalotia coriaria</i> (predatory beetles); <i>Stratiolaelaps scimitus</i> (predatory mites); <i>Steinernema feltiae</i> (nematodes)
LATE BLIGHT	Look for sunken, water-soaked lesions on leaves and brown lesions on tomato stems or on potatoes bedding plants.	Overwinters in potato cull piles or outdoors in field soil that is not completely frozen, so is not generally considered a problem for locally grown tomato transplants.	
LEAFMINERS (Spinach and beet leafminers)	Look for small, oblong, white eggs that are laid in neat clusters on the undersides of the leaves. Inside the mines look for one or several pale, white maggots.	Scout undersides of leaves (beets, spinach, Swiss chard) for eggs and treat when they are first observed in order to target larvae as they hatch.	The wasp parasitoid, <i>Diglyphus isaea</i> , which is most often used against <i>Liriomyza</i> leafminers (see Celery section) has also been reported to control leafminers in chard and works best in warm weather.
POWDERY MILDEW	Scout weekly. Look for faint, white fungal threads and spores on leaves.	Scout near vents, or any location with a sharp change between day and night temperatures.	Biological fungicides: <i>Bacillus amyloliquefaciens</i> ; <i>Bacillus subtilis</i> ; <i>Reynoutria sachalinensis</i> extract; <i>Streptomyces lydicus</i>
SHORE FLIES	Use yellow sticky cards to monitor for adults.	Found near algae, their food source. Black frass flecks the leaves. Larger than thrips frass.	<i>Dalotia coriaria</i> (predatory beetles); <i>Steinernema carpocapsae</i> (nematodes)
SLUGS	Look for chewed holes in leaves and shiny patches of slime. Slugs hide under dense foliage, beneath pots and benches and in other protected locations.	Chewed, irregular holes with smooth edges in leaves and slime that dries into silvery trails on foliage.	
SPIDER MITES (Two-spotted spider mites)	Rely on plant inspection. Look for light flecking, speckling or discolored foliage, and webbing if high populations have developed.	Look in hot, dry locations in greenhouse (i.e., near furnace) or near entrance ways.	<i>Amblyseius andersonii</i> (predatory mites); <i>Neoseiulus (Amblyseius) fallacis</i> (predatory mites); <i>Feltella acaruzuga</i> (predatory midge); <i>Neoseiulus (Amblyseius) californicus</i> (predatory mites); <i>Phytoseiulus persimilis</i> (predatory mites).
THRIPS (Western flower thrips)	Rely on sticky cards (placed just above crop canopy) and foliage inspection of key plants for early detection and to evaluate treatments.	Inspect plants by tapping tender new growth over a sheet of white paper. Watch for curled emerging leaves, distorted new growth on pepper. Look for white scarring and black frass (size of pin point) on cucumber and eggplant.	<i>Amblyseius swirskii</i> (predatory mites); <i>Neoseiulus (Amblyseius) cucumeris</i> (predatory mites); <i>Orius</i> spp. (pirate bug, predator); <i>Steinernema feltiae</i> (nematodes); <i>Stratiolaelaps scimitus</i> (predatory mites); ornamental pepper banker plants: Purple Flash® and Lobularia for Orius.
TOBACCO MOSAIC VIRUS	Dark line patterns and distortion of leaves.	Spread by plant handling (no insect vector).	
TOSPOVIRUS Impatiens Necrotic spot virus (INSV) & Tomato spotted wilt virus (TSWV)	Symptoms will vary depending upon the host. On pepper, look for necrotic spots on the leaf. Ringspots may also develop. On tomato, leaves may develop small, dark brown spots.	Thrips populations may be highest at front and rear of the greenhouse. Use fava bean or petunia indicator plants to determine if thrips are carrying the virus. Symptomless weeds may also be a source of virus.	None. See thrips.
WHITEFLIES	Rely on plant inspection to detect immature stages. Use sticky cards to monitor for adults.	Egg laying adults are found on the uppermost tender leaves of tomatoes, eggplant, and leafy greens. Immature stages are found on the undersides of leaves.	<i>Amblyseius swirskii</i> (predatory mites); <i>Chrysoperla</i> spp. (Green lacewing, predator); <i>Delphastus pusillus</i> (catalinae) (predatory beetles); <i>Dicyphus hesperus</i> (predatory bug); <i>Encarsia formosa</i> (Greenhouse whitefly parasite); <i>Eretmocerus eremicus</i> (Sweet potato whitefly parasite).

but take some time to research the diseases that are giving you the most trouble to find other strategies to incorporate into the disease management plan.

Seed Treatments for Disease Management

Seed treatments are useful for many vegetable crops to prevent root diseases, as well as certain diseases carried on or within the seed. There are two general types of seed treatment: eradivative and protective. Eradivative seed treatments use hot water or chlorine to kill disease-causing agents on or within the seed. They are useful in controlling certain seed-borne bacterial diseases such as bacterial leaf spot on pepper and tomato and bacterial canker on tomato. Protective seed treatments use fungicides on the seed surface to protect the seed against decay and soil-borne organisms such as damping off caused by *Pythium*, *Phytophthora* and *Rhizoctonia*. For more information regarding seed treatments, contact your seed sales representative, Extension vegetable specialist, or plant pathologist.

Sanitation

Pest management on vegetable bedding plants and transplants begins with a clean, weed-free, disinfected greenhouse. Before growing the crop, the greenhouse should be cleared of plant debris, weeds, flats and tools. Empty benches, potting tables, storage shelves, tools and cell packs should be washed and disinfected with a sanitizing agent. It is important to thoroughly clean or power wash to remove organic debris from plastic containers before using a sanitizing agent. Bits of organic debris can be difficult to remove and the organic matter can be a source of disease causing pathogens if the containers are reused.

After the greenhouse has been sanitized, care must be taken to avoid recontamination with pathogens. Purchase certified, disease-free seed from reliable sources. If possible, purchase seed that has been disinfested by chemical and/or heat treatment by the seed company. Potting media is easily reinfested by dirty hose nozzles or tools and unsanitary growing conditions. The floor of the greenhouse is a good source for diseases. Use a hook to keep the hose nozzles off the floor. Grow transplants off the ground in a well-ventilated greenhouse. To prevent root rot diseases, avoid over-watering and over-fertilizing. Water early in the day to allow foliage to dry quickly to help prevent foliar diseases.

Use separate greenhouses for vegetable seedlings and ornamental bedding plants. Separate greenhouses: 1) will protect vegetable seedlings from insect pests that may migrate from ornamentals and plants that are held over; 2) will help protect vegetable seedlings from Tospoviruses (i.e. Tomato spotted wilt virus) due to migrating infected thrips; 3) protect vegetable transplants from diseases that ornamentals may also be susceptible to (i.e. curcurbit seedlings from powdery mildew on calibrachoa and petunia and some cultivars of verbena) or tomato transplants from late blight on petunias); and 4) facilitate treatment of the vegetable seedlings if pesticides are needed.

Keep tomato transplant production separate from greenhouse tomato fruit production. Greenhouses with both young transplants and mature plants increase the risk of perpetuating diseases.

Techniques to Reduce High Humidity

High relative humidity is one of the major contributing factors to Botrytis blight and powdery mildew, common

fungal diseases of bedding plants. Warm air holds more moisture than cool air. During warm days, the greenhouse air is more humid. As the air cools in the evening, the moisture-holding capacity drops until the dew point is reached. Water then begins to condense on surfaces. Humidity can be reduced by exhausting the moist air and replacing it with cooler outside air that is drier. The method and time it takes to heat and vent depend upon the heating and ventilation system in the greenhouse. In greenhouses with vents, turn the heat on and crack the vents open about one inch. The moist humid air escapes from the vents. In greenhouses with fans, activate the exhaust fans for a few minutes and then heat the greenhouse to raise the air temperature. Then, shut off the fans. A clock can be set to activate the fans. The cooler, outside air will lower humidity levels as it is warmed in the greenhouse. A relay may be needed to lock out the furnace or boiler until the fan shuts off so that flue gases are not drawn back into the greenhouse. This will also help to prevent air pollution damage (ethylene or sulfur dioxide) to sensitive seedlings. Heat and vent two or three times per hour in the evening after the sun goes down and early in the morning at sunrise. Heating and venting can be effective even if it is cool and raining outside.

Air movement, even in a closed greenhouse, helps reduce moisture on the plant surfaces and surrounding the plants. Using horizontal airflow (HAF) can also reduce condensation. HAF fans keep the air moving in the greenhouse, helping to minimize temperature differentials and cold spots where condensation occurs. Air that is moving is continually mixed. The mixed air along the surface does not cool below the dew point so does not condense on plant surfaces.

HAF fans are more efficient than low-cost residential fans which are generally not designed for greenhouse conditions.

In addition, cultural practices can be used to reduce humidity within the plant canopy. These include proper watering practices and spacing of plants. Since most vegetable bedding plants are grown in flats that are spaced flat to flat, reducing humidity within the canopy is difficult. Proper planting dates, plant nutrition, watering practices and height management techniques help to prevent lush, overgrown plants thereby reducing humidity within the canopy.

Always water in the morning to reduce the length of time the leaves stay wet after irrigating to prevent foliar diseases. Rising temperatures during the day will evaporate water from the foliage, so the leaves stay dry. Avoid watering late in the day or when water will sit on leaf surfaces for long periods of time.

Fungicides and Bactericides

Fungicides can provide excellent management of some diseases, but for others they may be ineffective. In general, to control root diseases, broad-spectrum fungicides should be applied as a drench on a preventative basis. Read directions for application on pesticide labels. An application of additional water may be necessary. For foliage diseases, obtain thorough spray coverage and treat when disease is first evident.

Biological Disease Control Products

Biofungicides are biological fungicides that contain living organisms such as fungi or bacteria that attack plant pathogens and the diseases they cause. They can be used as part of an integrated disease management program to reduce

the risk of pathogens developing resistance to traditional fungicides. Currently, there are no pathogens that are resistant to biological fungicides.

Biological fungicides may suppress diseases in a number of different ways including direct competition or exclusion, antibiosis, predation or parasitism, induced resistance and plant growth promotion. Many biological fungicides work in multiple ways, such as by competition and parasitism, so are less likely to develop resistance than conventional fungicides that often work in a single way with a specific mode of action.

Direct Competition/ Exclusion: Before root infection can occur, pathogens must gain access to the zone closely associated with the root, known as the rhizosphere. For foliar diseases, the pathogen must make contact with the leaf or flower zone. The biofungicide grows a defensive barrier around this root, leaf or flower zone. The beneficial microbes compete with plant pathogens for nutrients, infection sites and space, excluding the pathogen.

Antibiosis: The biofungicide produces chemical compounds or secondary metabolites such as antibiotics or other toxins that kills the target organism. The biofungicide creates compounds that inhibit fungal or bacterial spores from germinating and causing plant disease, or the compounds restrict the pathogen's growth.

Predation or Parasitism: The biofungicide attacks and feeds on the pathogen, producing cell wall degrading enzymes, inhibiting or killing the pathogen.

Induce Resistance to the Host Plant: The biofungicide triggers the host plant to turn on its own defense mechanisms. Plants produce salicylic acid (a derivative of aspirin) which travels to other parts of the plant and signals these tissues to activate their natural defense mechanisms. This is also known as systemic acquired resistance (SAR), which improves the plants' response to pathogen attack by priming the metabolism of plant defense compounds.

Plant Growth Promotion: The biofungicide promotes root and shoot growth in the absence of disease causing pathogens. There may be increased nutrient availability of iron and other micronutrients by changing the pH or enzymes to help dissolve insoluble elements.

Benefits of Biological Fungicides

- Reduced risks to applicators and the environment.
- Shorter re-entry intervals and days to harvest intervals than many conventional fungicides.
- Many are labeled for use on edible crops including herbs and vegetables.
- Most (not all) are OMRI approved for organic production. Check company labels or websites or see the OMRI website at www.omri.org.
- Less chance of plant damage, but not always, so consult product labels.
- Generally compatible with beneficial predators and parasites (natural enemies), beneficial nematodes (check company websites for more information).
- Can improve nutrient uptake of certain elements.
- Can be used in rotation with conventional chemicals to reduce the risk of pathogens developing resistance to conventional fungicides (especially systemic fungicides).
- Not genetically modified.

Limitations of Biological Fungicides

- Must be used preventively, for they will not cure diseased plants.
- Must be used with proper cultural controls for plant growth, including clean starter material.
- Must use strict sanitation protocols.
- Have a shorter shelf life of 1-2 years (consult labels) than conventional fungicides and need to be stored under proper conditions.
- May need to be re-applied more often than conventional fungicides.
- May need to integrate traditional fungicides in rotation for more aggressive pathogens.

A number of products are commercially available for use on vegetable bedding plants and transplants. See Table 19 for information on labeled crops and diseases for these biological fungicides.

Fungal Diseases

Basil Downy Mildew

Downy mildew (*Peronospora belbahii*) is a recent problem on basil (grown in the greenhouse and in the field). It was first reported in Florida in 2007 and has been found in New England since 2008. All sweet basil cultivars are very susceptible to downy mildew. The least susceptible basil includes the lemon and spice types. Efforts are being made to breed new basil varieties with resistance to downy mildew.

Symptoms: Infected leaves develop a diffuse yellowing that is easily confused with nutrient deficiency. Distinct vein bounded patches on the underside of the leaves develop that produce dark purple-brown sporangia. The fuzzy, dark growth makes leaf undersides appear dirty.

Management: Management of environmental conditions such as temperature, humidity and duration of leaf wetness, sound cultural practices and fungicides will help prevent disease development. The pathogen needs at least 6 hours of leaf wetness and at least 12 hours for severe infections to develop. The optimum temperature for basil downy mildew to develop is 68°F, with no basil downy mildew growth below 53°F or above 77°F.

- Start with disease-free seed. Ask if your supplier is steam treating their basil seed. (Basil seed produces a gelatinous exudate, so it is difficult to use hot water seed treatments).
- Buy seed from a trusted source. Talk to your supplier about how the seed was produced, if it has been tested. The pathogen may be seed borne, but the mechanisms involved are not well known and testing is difficult.
- Purchase basil downy mildew resistant varieties. VDF Specialty Seeds has recently introduced three new downy mildew resistant varieties: Rutgers Obsession DMR for both field and potted plant production, Rutgers Devotion DMR for potted plant production and Rutgers Thunderstuck DM for field production. In 2018, they started selling these varieties to commercial basil growers. Proven Winners has developed the downy mildew resistant variety, Amazel. Other tolerant varieties include Everleaf, Prospera, or Red Rubin.
- If you purchase plugs or transplants, inspect them carefully upon arrival.

Table 19: Fungicides and Bactericides Labeled for Vegetable Transplants			
Fungicide	Target Pests	Labeled Crops	Comments
azoxystrobin (Heritage) REI 4h, Group 11	Leaf spots and blights, downy mildew, Botrytis blight, powdery mildew, downy mildew (depending upon crop, see label)	Vegetable plants grown for transplanting such as Cole crops, bulb vegetables, cucurbits, leafy vegetables, peppers	Preventative and curative broad-spectrum fungicide. See supplemental label for use on vegetable transplants.
azoxystrobin & benzovindiflupyr (Mural) REI 12h, Group 11 and 7	Leaf spots and blights, downy mildew, powdery mildew (depending upon crop, see label)	Vegetable transplants grown for resale to consumers - cucurbits, fruiting vegetables, tomatoes	A broad-spectrum fungicide for foliar applications (with translaminar activity) for plants grown for resale to consumers.
basic copper sulfate (Cuprofix Ultra 40 Dispers, Cuproxat, Ciuproxat FL 05) REI 48h, Group M1	Various leaf spots and blights, downy mildew, bacterial blight, late blight on tomatoes, bacterial spot (depending upon the crop, see label)	Many vegetables including cucumbers, eggplant, peppers, tomatoes	Preventative, contact fungicide. Crops grown in the greenhouse may be more sensitive to copper injury so the user should determine plant sensitivity. Observe for 7 to 10 days for symptoms of injury.
Bacillus amyloliquifaciens D 747 (Double Nickel) ⁰⁵ , Triathlon BA ⁰⁵ REI 4h, Group 44	Fungal and bacterial leaf spots and blights, downy mildew, powdery mildew, damping off (depending upon the crops, see labels).	Many vegetables including Cole crops, bulb vegetables, cucurbits, fruiting vegetables, leafy vegetables and others	Broad-spectrum, preventative biological fungicides. Begin applications when conditions in the greenhouse favor disease development.
Bacillus amyloliquifaciens F722 (Stargus ⁰⁵) REI 4h	Bacterial spot and blights, botrytis blight, late blight, damping off and root rots, downy mildew (depending upon crops, see label)	Many vegetables	Broad-spectrum preventative biological fungicide for growing media or foliar applications. Activates ISR (induced systemic resistance).
Bacillus subtilis QST 713 (Cease ⁰⁵) REI 4h, Group 44	Fungal and bacterial leaf spots, powdery mildew, Botrytis blight, downy mildew. Soil drench to suppress damping off and root rots (see label).	Many vegetables including Cole crops, cucurbits, fruiting vegetables, leafy vegetables, bulb vegetables	Broad-spectrum, preventative biological fungicide. Begin applications when conditions in the greenhouse favor disease development.
Bacillus subtilis GB03 (Companion VP Biological Fungicide ⁰⁵) REI 4h, Group 44	Damping off fungi, root rots (<i>Fusarium</i> , <i>Pythium</i> , <i>Phytophthora</i> , <i>Rhizoctonia</i>)/Botrytis blight, leaf spots, (fungal and bacterial), late blight, powdery mildew	Many vegetables including Cole crops, cucurbits, fruiting vegetables, leafy vegetables, bulb vegetables	Preventative biological fungicide for control and suppression of soil and foliar diseases. Activates ISR (induced systemic resistance).
Bacillus subtilis MB1 600 (Subtlix NG), REI 4h, Group 44	Botrytis blight, powdery mildew, damping off and root rots (depending upon crops, see label).	Cucurbits, fruiting vegetables	Preventative biological fungicide for growing media or foliar applications.
boscalid & pyraclostrobin (Pageant Intrinsic) REI 12h, Group 7 & 11	Crown rots (<i>Fusarium</i> , <i>Rhizoctonia</i>), damping off (<i>Rhizoctonia</i> , <i>Pythium</i>), downy mildew, fungal leaf spots & blights, Phytophthora blight, botrytis blight, powdery mildew	Tomato transplants for the home consumer market	Preventive, broad-spectrum fungicide. Pyraclostrobin has local systemic activity and translaminar activity. Do not use for tomato transplants for agricultural production fields.
copper hydroxide (Champ Dry Pritl) REI 24/48h, (Kalmor ⁰⁵) REI 24/48h, (Kocide 2000) (Kocide 3000) REI 48h, Group M1	Leaf spots, anthracnose, bacterial spots, late blight and other diseases (see label)	See labels for specific crops	Protectant, contact fungicide. See labels for plant safety information.
copper oxychloride & copper hydroxide (Badge X2 ⁰⁵) (Badge SC) REI 24h, Group M1	Bacterial and fungal leaf spots and blights (depending upon crop, see labels)	Greenhouse crops including eggplant, pepper, tomato	Contact fungicides. Badge X2 is a low load dry copper formulation that is a mixture of two high purity copper salts (copper oxychloride and copper hydroxide). Badge SC is a liquid formulation. See labels for plant safety information.
copper octanoate (Camelot 0 ⁰⁵) REI 4h, Group M1	Bacterial and fungal leaf spots (many), powdery mildew, downy mildew, early blight, late blight and others (depending upon crop)	Cole crops, lettuce, onion, tomato, eggplant, pepper, cucurbits, leafy vegetables and others	Contact fungicide. See label for specific usage instructions and plant safety information.
copper sulfate pentahydrate (Phyton 35), REI 48/24h, Group M1	Fungal and bacterial leaf spots (see label for specific crops/pests), downy mildews, powdery mildews, Botrytis blight, late blight on tomatoes	Cole crops, cucurbits, eggplant, pepper, tomato	Systemic, preventative, and curative bactericide/fungicide. Thorough coverage needed. See label for plant safety information.
cyazafamid (Ramman), REI 12h, Group 21	Pythium damping off of tomato, downy mildew on basil	Basil and tomato greenhouse transplants.	Locally systemic fungicide. Apply as a drench.
fenhexamid (Decree 50 WDG) REI 12h, Group 17	Botrytis blight	Tomatoes, cucumber, leafy greens (except spinach)	Preventative, translaminar fungicide. Do not apply in vegetable agricultural fields.
fludioxonil (Spirato GHN) REI 12h, Group 12 (Emblem) REI 12h, Group 12	Leaf spots and blights, powdery mildew, botrytis blight (depending upon crop, see label)	Vegetables including seedlings and transplants such as Cole crops, leafy vegetables	Protectant fungicide for certain vegetable seedlings and transplants. Not for field vegetable production use.
Gliocladium catenulatum J1446 (Prestop WG ⁰⁵) REI 4h (Pvent ⁰⁵) REI 4h	Damping off, root and stem rot (<i>Alternaria</i> , <i>Pythium</i> , <i>Phytophthora</i> , <i>Rhizoctonia</i>), Botrytis blight	Greenhouse vegetables (see label for specific types)	Preventative biological fungicides that can be incorporated into the media, applied as a drench or foliar spray.
hydrogen dioxide & peroxyacetic acid (Zero To 2.0 ⁰⁵) REI 0h, REI 1h (spray)	Downy mildew, powdery mildew, leaf spots and blights, root rots (see label)	Cucumbers, eggplant, peppers, tomatoes, lettuce	Contact fungicide. Strong oxidizing agent. See label for plant safety information.
mandipropamid (Micora), REI 4h, Group 40	Downy mildew, Phytophthora blight, late blight on tomatoes (depending upon crop, see label)	Leafy and vegetable transplants grown in enclosed greenhouse, with permanent flooring for resale to consumers	Contact, protectant and translaminar fungicide for vegetable and basil transplants for sale to consumers.
mefenoxam (Subdue Maxx) REI 0/48h Group 4	Damping off (<i>Pythium</i> spp.), Crown Rot (<i>Phytophthora</i> spp.) and downy mildew (depending upon crop, see label)	Cole crops, cucurbits, fruiting vegetables, leafy vegetables, bulb crops transplants grown for retail sale to consumers	Systemic fungicide for vegetable transplants grown for retail sale to consumers
mineral oil (Suffoil X0G), REI 4h	Powdery mildew	Greenhouse vegetables (see label)	Contact fungicide. See label for plant safety information.
pentachloronitrobenzene (PCNB) (Terraclor 400) REI 12h, Group 14	Root and stem rot, damping off (<i>Rhizoctonia solani</i> , <i>Pellicularia filamentosa</i>)	Vegetable bedding plants	Protectant, contact fungicide. Apply as a soil drench.

Table 19: Fungicides and Bactericides Labeled for Vegetable Transplants (continued)

Fungicide	Target Pests	Labeled Crops	Comments
penhiofpyrad (Fontelis), REI 12h, Group 7	<i>Alternaria</i> , Botrytis blight, powdery mildew and various leaf spots and blights (depending upon crop, see label)	Tomatoes, peppers and edible peel cucurbits (cucumbers, summer squash)	Broad-spectrum fungicide with preventative, curative and locally systemic activity. See label for plant safety information.
phosphorus acid (Alude) REI 4h, Group 33	Downy mildew, <i>Phytophthora</i> spp.	Brassicas, cucurbits, peppers, tomatoes, leafy vegetables	Systemic fungicide. See label for plant safety information.
phosphorous acid & hydrogen peroxide (OxiPhos), REI 4h	Downy mildew, powdery mildew, root rots (<i>Phytophthora</i> , <i>Pythium</i> , <i>Fusarium</i> , <i>Rhizoctonia</i>)	Many vegetables (see label)	Systemic fungicide. See label for plant safety information.
polyoxin D zinc salt (Affirm WDG) REI 4h, Group 19	Downy mildew, powdery mildew, black rot (Cole crops), leaf spots & blights (depending upon crops, see label) Cucurbit vegetables: Powdery mildew, <i>Botrytis</i> , <i>Corynespora</i> leaf spot, scab, early blight; Fruiting vegetables: Powdery mildew, <i>Botrytis</i> , early blight, suppression of anthracnose	Cucurbit vegetables, fruiting vegetables (eggplant, pepper, tomato)	Strong oxidizing agent. Do not use at higher than labeled rates as leaf burn may result. Preventative and curative fungicide. Active ingredient (polyoxin) is a natural antibiotic and fermentation product of a soil bacterium.
potassium bicarbonate (Milstop ⁰⁵) REI 1h (Kaligreen ⁰⁵) REI 4h	Powdery mildew and others (see labels for more information)	Many vegetables (see labels)	Contact fungicides with eradicant activity. Thorough coverage essential. Potassium bicarbonate disrupts the potassium ion balance in the fungus cell, causing the cell walls to collapse.
propanoic acid hydrochloride HCl (Previcur Flex) REI 12h, Group 28	Root rot and damping off (<i>Pythium</i> , <i>Phytophthora</i>)	Tomatoes, cucurbits, peppers, greenhouse leaf lettuce	Systemic fungicide. Apply in the evening. Phytotoxicity may occur if applied directly to dry growing media, especially in intense sunlight.
pyrimethanil (Scala SC) REI 12h, Group 9	Gray mold (<i>Botrytis</i>), early blight (<i>Alternaria</i>)	Tomatoes	Preventative fungicide. Apply only in well-ventilated greenhouses and ventilate for at least 2 hours after application. Phytotoxicity may occur in unventilated greenhouses with relative humidity above 80%.
Reynoutria sachalinensis extract (Regalia GC ⁰⁵) REI 4h, Group P5	Botrytis blight, damping off, powdery mildew, downy mildew, bacterial leaf spot, early and late blight (depends upon crop)	Many vegetables including bulb, Cole crops, cucurbits, fruiting vegetables, leafy vegetables	Preventive, biological fungicide with translaminar activity. Plant activator. Formulation of an extract from giant knotweed. Use preventatively to increase the natural defense system of plants.
Streptomyces griseoviridis K 61 (Mycostop ⁰⁵) (Preference) ⁰⁵ REI 4h	Damping off, and root rots (<i>Fusarium</i> , <i>Pythium</i> , <i>Phytophthora</i>) Botrytis blight (suppression)	Many vegetable transplants	Preventative biological fungicide. Contains a beneficial bacterium. Repeat applications may be needed. Use as a soil spray or drench.
Streptomyces lycicus WYEC 108 (Actinovate AG ⁰⁵) REI 1h	Suppression of root rots (<i>Fusarium</i> , <i>Rhizoctonia</i> , <i>Pythium</i> , <i>Phytophthora</i>), and foliar diseases (downy mildew, powdery mildew, Botrytis, Alternaria)	Many greenhouse vegetables	Preventative biological fungicide applied as a soil spray or drench.
streptomycin sulfate (Agri-mycin 17 ⁰⁵) REI 12h, Group 25	Bacterial spot and speck	Tomatoes and pepper transplants	Xylem mobile systemic fungicide. Repeated applications can result in resistant bacteria.
sulfur (Microthiol Dispers ⁰⁵) (Micro Sulf ⁰⁵) REI 24h, Group MZ	Powdery mildew	See labels	Contact fungicides. Crops grown in greenhouses may be more sensitive to sulfur injury, so the lowest label rate should be tried initially. Do not use within two weeks of an oil spray treatment.
Swinglea glutinosa extract (EcoSwing ⁰⁵) REI 4h	Alternaria leaf spot, Botrytis blight, powdery mildew	Many vegetables	Preventive biological fungicide. Activates ISR (induced systemic resistance). Thorough coverage is needed.
thiophanate methyl (3336 F), REI 12h Group 1	Anthracocone, botrytis blight, powdery mildew	Vegetable transplants such as cucurbits and beans	Xylem mobile systemic fungicide. Resistant populations of <i>Botrytis</i> are common in the greenhouse. Not for field vegetable production.
Trichoderma asperellum (ICC012) & Trichoderma gamsii (ICC 080) (Bio-Tam 2.0 ⁰⁵ , Obtego ⁰⁵) REI 4h Group BM02	Root rots (<i>Fusarium</i> , <i>Phytophthora</i> , <i>Pythium</i> , <i>Rhizoctonia</i> , and <i>Thielaviopsis</i>)	Many greenhouse vegetables including Cole crops, fruiting, leafy and root vegetables	Preventative biological fungicides. See label for specific directions for drenches based upon container size.
Trichoderma harzianum T-22 (RootShield AG ⁰⁵) REI 0h (RootShield Granules ⁰⁵) REI 0h Group BM02	Root rots (<i>Pythium</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , and <i>Thielaviopsis</i>)	Many vegetables (see labels)	Preventative biological fungicides. Apply as a soil drench (RootShield AG) or incorporate into greenhouse planting mix (RootShield Granules)
Trichoderma harzianum KRL-AG2 (RootShield WP ⁰⁵) REI 0h Group BM02	Root rots (<i>Pythium</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> and <i>Thielaviopsis</i>)	Many vegetables	Preventive biological fungicide. Apply as a soil drench with no overhead spray/
Trichoderma harzianum T-22 & Trichoderma virens G-41 (RootShield Plus WP ⁰⁵) REI 4h (RootShield Plus G ⁰⁵) REI 0h Group BM02	Root rots (<i>Pythium</i> , <i>Phytophthora</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , and <i>Thielaviopsis</i>)	Many vegetables (see labels)	Preventative biological fungicide. Apply as a soil drench (RootShield Plus WP) or incorporate into greenhouse planting mix (RootShield Plus Granules).
Ulocladium oudemansii U3 (BotryStop) ⁰⁵ REI 4h	Botrytis blight	Many vegetables	Preventive biological fungicide. Thorough coverage needed.

The symbol ⁰⁵ indicates a pesticide is listed by the Organic Materials Review Institute (OMRI) as approved for use in certified organic production. This information is supplied with the understanding that no discrimination is intended and no endorsement implied. Due to constantly changing regulations, we assume no liability for suggestions. If any information in these tables is inconsistent with the label, follow the label.

- Monitor plants at least once a week. Inspect plants in areas where the air movement is the lowest, such as the central part of the greenhouse or the middle of benches.
- It is vital to reduce humidity and leaf wetness duration to prevent spore germination. See Techniques to Reduce High Humidity, page 52.
- Provide good air circulation and reduce humidity within the canopy. Proper planting dates, fertility, watering and height management will prevent overgrown plants, thereby reducing humidity within the canopy.
- Water in the morning, never late in the day. Rising temperatures during the day will cause water to evaporate from the foliage and dry the leaf surface.
- Consider use of sub-irrigation to keep leaves dry.
- If fungicides are used, they need to be applied preventatively on a regular schedule, before plants are infected. If contact fungicides are used, thorough coverage is needed to the underside of the leaves.
- If you see symptoms of downy mildew, immediately destroy the infected plants, clean and sanitize the greenhouse.
- After you discard the infected plants, protect adjacent plants with fungicides.
- Plan on planting and harvesting basil early.

For Garden Retailers: Dr. Meg McGrath, Cornell University suggests encouraging home gardeners to grow some plants in containers that can be brought inside when humidity outside is high (overnight and on rainy days). The pathogen needs at least 85% humidity to be able to infect.

Botrytis blight

Botrytis can cause leaf blight, stem cankers, damping off and root rot. Plants may be attacked at any stage, but the new tender growth, freshly injured tissues and dead tissues are most susceptible.

Symptoms: *Botrytis* blight produces characteristic gray fuzzy-appearing spores on the surface of leaves and stems. Young leaves may become infected and then progress to the stem with tan stem cankers developing on basil and tomato.

Air currents and splashing water can easily disseminate the spores. In general, germination of spores and infection is dependent on a film of moisture lasting 8-12 hours, relative humidity of 93% or greater and temperatures between 55° and 65°F. After infection, colonization of plant tissues can occur at temperatures up to 70°F.

Management: *Botrytis* diseases can only be managed by a combination of methods including manipulation of environmental conditions (temperature, humidity and duration of leaf wetness), sound cultural practices and use of fungicides. Fungicides alone cannot control *Botrytis* and this pathogen has a long history of fungicide resistance development.

- Control weeds and remove plant debris before and during production.
- Dispose of diseased plants and debris in a plastic trash bag. Keep the bag closed to help prevent spreading spores to uninfected plants as the bag is removed from the greenhouse. Cover trash cans to prevent the airborne spread of spores from diseased plant tissue.
- Reduce humidity and leaf wetness duration to prevent spore germination. See Techniques to Reduce High

Humidity, page 52. Provide good air circulation and reduce humidity within the canopy.

- Proper planting dates, fertility, watering and height management will prevent overgrown plants, thereby reducing humidity within the canopy.
- Water in the morning, never late in the day. Rising temperatures during the day will cause water to evaporate from the foliage and dry the leaf surface.
- Avoid growing ornamental hanging baskets above vegetable bedding plants. Spent flowers dropping on plants below cause *Botrytis* infection.

Damping-off of Seedlings

Damping-off is a common disease of germinating seeds and young seedlings. Several fungi are capable of causing damping-off including *Rhizoctonia*, *Alternaria*, *Sclerotinia* and the water molds, *Phytophthora* and *Pythium*. Soil-borne fungi generally do not produce air-borne spores but are easily transported from contaminated soil to pathogen-free soil by infected tools, hose ends, water-splash and hands. Young seedlings are most susceptible to damping-off. However, later in the crop cycle, the same pathogens may cause root and stem rot.

Symptoms: Symptoms of damping-off include seedlings failing to emerge or wilting, often with a stem lesion that appears water-soaked or dark, necrotic and sunken at the soil line. Pathogens usually spread radially from a central point of origin so plants often die in a circular pattern. Vegetable seeds that are germinated in poorly drained, cool soils are especially susceptible. Young plants that do emerge are weak and often wilt at or below the soil line. Cabbage, cauliflower, tomato and pepper seedlings may be girdled by brown or black sunken cankers. Stems of these plants may shrivel and become dark and woody (wirestem or collar rot). The plants may not collapse, but remain stunted and die after transplanting.

Management: Damping-off must be prevented because it is difficult to stop once symptoms occur. There are several strategies to prevent damping-off.

- Use only certified disease-free seed from reputable seed companies.
- Use fungicide-treated seed. Certain fungicides are labeled for damping-off for selected vegetable crops.
- Use pasteurized soil, properly produced compost-based or soilless mixes. Apply biological fungicides as a drench at planting or incorporate.
- Disinfect all flats, cold frames, pots and tools.
- Germinate seed under conditions that will ensure rapid emergence, using bottom heat.
- Avoid overwatering, excessive fertilizer, overcrowding, poor air circulation, careless handling, and planting too deeply.
- Fill flats with pre-moistened growing media to avoid compaction. Lightly fill and brush containers. Do not pack young plants into containers, use pre-dibbled holes for transplants.
- To avoid compaction, do not stack or “nest” filled trays or pots.
- Provide adequate light for rapid growth.
- Apply biological fungicide as a drench at planting or incorporate into the growing media
- Discard entire infected flats.

Late Blight

Late blight is caused by the water mold *Phytophthora infestans*. The fungus-like organism typically overwinters in potato cull piles or in soil where plant tissue has not completely frozen and is not considered a problem for locally grown tomato seedlings. However the disease can be a problem on potato bedding plants. Late blight is not seed borne in tomatoes but can be carried on potato tubers used for bedding plant production. Petunias and tomatoes are in the solanaceous family and are susceptible to late blight. Using drip irrigation of petunia hanging baskets helps to minimize long periods of leaf wetness which is conducive to late blight. In addition, in order to decrease the possible spread of late blight from one host to another, petunias and tomatoes should not be grown in close proximity (avoid placing hanging basket petunias over tomatoes and grow bench crops in separate greenhouses).

Symptoms: Common symptoms on tomatoes and potatoes are sunken, dark green or brown, water-soaked lesions on leaves and brown lesions on stems. White fuzzy growth sometimes develops under moist conditions. Leaf lesions begin as irregularly shaped olive green to brown spots and quickly grow larger—spots that are consistently small are most likely Septoria leaf spot. Confirm late blight by submission of a sample to a diagnostic laboratory.

Management: Oomycete-specific fungicides are required to manage late blight. Often treatments begin when the disease is reported nearby because it travels so quickly.

Powdery Mildew

Powdery mildew may occasionally occur on vegetable transplants including tomato, eggplant and other solanaceous crops, as well as cucurbit crops. Faint, white mycelium may develop on leaves and stems, with yellow margins.

Most growers are familiar with powdery mildew when it develops on cucurbits in the field. The powdery mildew that affects certain cultivars of calabrochoa, petunia and verbena can also infect cucurbit seedlings including squash, cucumbers and pumpkins. Growers who produce cucurbit transplants as well as calabrochoa, petunia and verbena should be especially careful to separate these crops. Fortunately, powdery mildew resistant verbenas are commonly available. It is possible that this powdery mildew could affect the cucurbit transplants that may not have otherwise become infected until the fruit was beginning to form in the field.

Bacterial Diseases

Bacterial diseases of vegetable bedding plants, such as bacterial leaf spot of peppers and tomatoes, bacterial speck & bacterial canker of tomatoes, and black rot on cole crops are introduced into a greenhouse through infected seed and transplants.

Bacterial leaf spot, Bacterial speck

Symptoms: Bacterial leaf spot is caused by *Xanthomonas campestris* pv. *vesicatoria* and is found primarily on peppers although all aboveground parts of tomatoes are also susceptible. Spots on leaves are chocolate-brown with yellowing at lesions' margins, and irregularly shaped with areas of dead leaf tissue. At first, the spots are less than 1/4 of an inch in diameter. Severely spotted leaves will appear scorched and defoliation may occur. This disease is most prevalent during moderately high temperatures and long periods of leaf wetness.

Bacterial speck occurs on tomato but not pepper. The bacterium, *Pseudomonas syringae* pv. *tomato*, causes small black spots to develop resulting in chlorosis (yellowing), necrosis (dead tissue) and blighting of the foliage. Bacterial speck can usually be distinguished from bacterial spot by the size of the lesions, however, in some cases, the symptoms look similar.

Bacterial canker

Symptoms: Bacterial canker of tomato is caused by *Clavibacter michiganensis* pv. *michiganensis* (formerly *Corynebacterium michiganense*). In New England, bacterial canker occurs less frequently than other tomato diseases but it is potentially more destructive. The bacterium is seed-borne but may survive on plant debris in soil for at least one year. It can also survive in the greenhouse on wooden stakes and flats. Wilt, leaf scorch, canker, pith necrosis and fruit spot may occur singly or in combination depending on the circumstances. When the bacterium is carried in the seed, the vascular system becomes colonized, resulting in wilt, pith necrosis and external cankers. Wilt initially occurs on one side of a leaf or one half of a plant because only a portion of the vascular system is blocked. Cankers and pith necrosis occur in later stages of disease development. Cankers are dark and water-soaked in appearance and often exude bacteria that are easily spread to adjacent plants. Pith necrosis is first evident as a darkening of the center of the stem that soon becomes chambered or hollow. When leaf scorch occurs, the petioles usually bend downward while the leaf edges curl up. The margins of the leaves become brown with a yellow border to the inside. Scorching of the foliage often develops in the absence of wilt or stem canker. Transplants may not express symptoms until six to eight weeks after infection and initial symptom expression is accelerated by environmental stress.

Black rot

Symptoms: Black rot, caused by the bacterium *Xanthomonas campestris* pv. *campestris* occurs where cruciferous plants are grown. All brassicas can be severely affected. The bacterium enters the leaves by colonizing the hydathodes (water pores) and moves from the leaf margins inward. Lesions may also begin at wounds. Diseased tissue is often V-shaped; flaccid, tan to yellow and with blackened veins. The blackened veins are diagnostic and are best seen by holding the leaf up to the light. When the lesions reach the petiole and stem, the bacterium moves systemically through the plant, resulting in premature leaf drop. At this stage of disease, a cross-section of the stem will reveal a ring of discolored vascular tissue.

Management of bacterial diseases: These bacteria can be introduced on infected seeds, infected transplants purchased from another operation, or in the field on crop residues. For example, black rot can survive on weeds in the same family as the host crop especially, mustard, shepherd's-purse and cruciferous weeds. Bacteria enter wounds created by insects, so keep insect pests under control. The management of these bacterial diseases is similar and includes the following strategies:

- Buy certified disease-free seed from a reputable source.
- Use hot water-treated seed. Ideally, the seed should be custom-treated by the seed company. Seed companies may treat the seed upon request. There is a risk that germination percentages will be reduced if the seed crop is grown under stressful environmental conditions.
- Promptly remove infected plants and adjacent plants to prevent further infection and avoid unnecessary handling of plant material.

- Avoid overhead irrigation, splashing or periods of extended leaf wetness.
- Disinfect all benches, equipment, flats and stakes.
- Follow sound practices for weed and insect control.
- Prevent bacterial leaf spot on peppers by choosing resistant varieties whenever possible. There are many resistant varieties of bell peppers available, but few resistant specialty peppers.

Viral Diseases

Some viral diseases of vegetable bedding plants include cucumber mosaic virus (CMV), tobacco mosaic virus (TMV) and the Tospoviruses, INSV and TSWV. There is no control for plants infected with a virus. It is important to have the virus disease accurately identified. Serological techniques such as ELISA (enzyme-linked immunosorbent assay) are now available to accurately identify a wide range of viruses. On-site grower kits using this same technology are also available from Agdia (www.agdia.com) to test for viruses such as CMV, TMV, INSV, and TSWV.

Cucumber mosaic virus

Cucumber mosaic virus (CMV) has a wide host range of over 400 species of plants including vegetables, ornamentals and weed hosts.

Symptoms: Infected plants may show mild mosaic patterns and mottling, flecking, and fern leaf distortion.

CMV is primarily spread by aphids that can acquire the virus in as little as 5 to 10 seconds. Aphids then move the virus from plant to plant for a few hours.

Management: Rogue diseased plants. Eliminate weeds such as common pokeweed, chickweed, field bindweed, yellow rocket, and bittersweet nightshade that may be reservoirs of CMV.

Tobacco Mosaic Virus (TMV)

TMV has a wide host range but is especially a concern on solanaceous crops. In recent years, TMV has been reported on pepper, calibrachoa, petunia, and tomato. TMV is not transmitted by insects! It is a very stable virus that can be spread by contact. Workers can easily spread TMV when they handle plants or when cutting tools become contaminated. TMV can persist in dried tobacco leaves, so tobacco products can also be a source of TMV.

Symptoms: Symptoms include yellow mottling, upward leaf curling and overall stunting. Some infected plants may not show any symptoms at all.

Management: Discard infected plants including roots, plant debris, potting media and associated plastic tags. Wear disposable gloves and discard gloves immediately afterwards. Carry the sealed plastic bags directly out of the greenhouse. Do this at the end of the working day. Disinfect hands by washing with milk, or tri-sodium phosphate and then thoroughly with soap and water. Smokers need to wash their hands before entering the greenhouse so they do not infect plants. In greenhouses, hard surfaces such as door knobs, or flats can become contaminated after handling virus-infected plants and remain a source of infection. Thoroughly disinfect the growing area with a commercial disinfectant. A 20% solution of non-fat dry milk can be used to wash contaminated hands or tools. Control perennial weeds in the Solanaceous family such as ground cherry and horsenettle that could be reservoirs of TMV.

Tospoviruses

Tospoviruses are a group of viruses that include impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV). They may infect hundreds of plant species including basil, tomatoes, peppers and eggplant. These viruses are primarily spread by the western flower thrips. Tospoviruses are not seedborne but are brought into the greenhouse on vegetatively propagated ornamental plants or seedlings that have been exposed to the virus. Once the thrips in the greenhouse become infected, they can transmit the virus to susceptible crops and weeds.

Symptoms: Symptoms include stunting, foliar ringspots and black lesions on stems. Symptoms of INSV and TSWV will vary depending upon the host.

Management: To manage Tospoviruses, it is necessary to discard infected plant material, including weeds and to manage thrips. Infected vegetable transplants planted into the garden or field will be stunted and will not produce a harvestable crop. Since INSV and TSWV are not seed-borne, vegetable transplants may be kept free of Tospoviruses if they are not brought into contact with other infested crops or thrips carrying the virus. Growers attempting to concentrate all their warm temperature crops in a single house run a risk of mixing Tospovirus-free vegetable seed crops with leftover ornamental stock plants or new cuttings that may carry the virus. Pre-finished or vegetatively propagated ornamentals from another producer could be infested with thrips or a virus. Therefore, vegetable bedding plants and ornamentals should always be grown in separate greenhouses.

TRANSPLANT INSECT AND MITE MANAGEMENT

Monitoring

A regular monitoring program is the basis of pest management. Conduct regular, weekly scouting to detect problems early.

Yellow Sticky Cards

Use yellow sticky cards to trap and detect adult stages of fungus gnats, thrips and whiteflies. Place one to four cards per 1,000 square feet. The cards should be spaced equally throughout the greenhouse in a grid pattern with additional cards located near doorways and vents. Place some cards just above the plant canopy (to detect thrips and whiteflies) and some of the cards on the rim of the flats or pots to detect fungus gnats. Inspect and replace the cards weekly to keep track of population trends.

Plant Inspection

Plant inspection is needed to assess general plant health and to detect diseases, mites and aphids plus any hot spots of immature whiteflies. Randomly select plants at ten locations in an area of 1,000 square feet, examining plants on each side of the aisle. Start this pattern at a slightly different location each week, walking through the greenhouse in a zigzag pattern down the walkway. Examine the underside of leaves for insect pests and inspect root systems to determine whether they are healthy.

Key Plants and Indicator Plants

Focus on scouting key plants and indicator plants. Key plants are those plants or cultivars that have serious, persistent problems every year. For example, peppers, leafy greens and eggplants

are prone to aphid infestations. Look for aphids on the young leaves and for shiny honeydew on the upper leaf surface. If grown near flowering plants, peppers and eggplant will also indicate an early thrips population. Look for distorted, young leaves with silvery flecked scars, signs of thrips feeding damage.

Fava beans and certain cultivars of petunia are used as indicator plants to detect the presence of thrips carrying INSV and TSWV. These plants will develop viral symptoms within one week if fed on by the infected thrips. The petunia cultivar 'Summer Madness' and several varieties of fava bean have been successfully used to detect tospoviruses. To use petunias and fava beans as indicator plants:

- Remove flowers from indicator plants to encourage feeding on foliage where symptoms can be observed.
- Place a blue non-sticky card in each pot at plant height. The blue card will attract thrips to the indicator plant. Blue plastic picnic plates work well.
- Place petunia plants throughout the greenhouse among the crop at a rate of one plant every 20 to 30 feet and fava bean plants at the rate of 12 pots per 1,000 sq. ft.
- Remove symptomatic leaves on petunia plants and continue to use the plants. The virus is not systemic in these plants. Thrips feeding injury leaves distinct white feeding scars on the foliage. Virus symptoms appear as a brown rim around the feeding scars.
- Remove entire plants of fava beans if symptoms are observed, because the virus is systemic in these plants. Viral symptoms appear as dark brown angular lesions on leaves or yellow to light green ring spots. Dark necrotic areas can also be seen on the stem. Fava beans have dark black spots on their stipules that should not be confused with viral symptoms.
- Replace with new plants, planting 1-2 bean seeds per 4" pot.

Record Keeping and Decision-Making

Each time the crop is scouted, record the pest numbers, their location and the number of plants inspected. Records on pest numbers and locations will help you identify population trends. Population trends will also indicate if initial control measures were successful or if they need to be repeated. Once this information is collected each week, a pest management decision can then be made. Monitoring and record keeping will answer the following questions and help you make the necessary treatment decisions. Is the population decreasing, increasing or remaining stable over the growing season? Do you need to spray? Are insects migrating from weeds under the benches to your crops? Is the treatment from last week working? See Tables 19 (page 54) and 20 (page 62) for selected materials labeled for managing insects, mites and diseases on greenhouse-grown vegetable transplants. Follow label instructions before using the material on vegetable bedding plants. The product must be used only for crops for which the compound is registered.

Biological Control for Insects and Mites

Biological control agents are commercially available for use against aphids, spider mites, cyclamen mites, broad mites, fungus gnats, shore flies, thrips and whiteflies. Natural enemies are living organisms that need to be released when pest populations are low. They do not act as quickly as pesticides so cannot be used as a rescue treatment. Natural enemies (parasites, predators or pathogens) are best used

early in the cropping cycle when plants are small, pest numbers are low and damage is not yet observed. A detailed plan of action is needed to insure success. Accurately identify the key pests in your production system. Natural enemies, especially parasites, are often very specific to a particular pest. Many insecticide residues can adversely affect natural enemies for up to 4 months after their application. For more information on the compatibility of pest control materials with natural enemies, refer to online resources, such as:

- 1) Koppert's online interactive database: www.koppert.com
- 2) Biobest: <http://www.biobestgroup.com/> (click on "side effect manuals")
- 3) BASF (formerly Becker Underwood), Nemasys chemical compatibility guide: <https://www.evergreengrowers.com/fileuploader/download/download/?d=0&file=custom%2Fupload%2FFile-1385102870.pdf>
- 4) BioWorks Botanigard biocompatibility: Bioworks BotaniGard biocompatibility
- 5) Bioline Agrosociences

Start in a small trial area to become familiar with releasing, monitoring and evaluating the effectiveness of natural enemies. With help from your supplier and University specialist, establish a schedule for introducing the natural enemies. Release rates and timing will vary depending upon the crop and its size, the degree of infestation, effectiveness and type of natural enemies, plus the time of year. Vegetable bedding plants with only one or two key insect pests or with a longer production schedule may be logical candidates for biological control. Some growers have started with using biological controls against fungus gnats (beneficial nematodes) and thrips (predatory mites), especially if long term crops are in the same greenhouse. Be sure that natural enemies are received from your supplier quickly (within 4 days), and that they are kept cool during shipment. Inspect natural enemies for viability and quality when they are received. Biological control suppliers often send a description of what to look for when receiving the natural enemies. For more specific information with color photos, see *Grower Guide: Quality Assurance of Biocontrol Products* compiled by Dr. R. Buitenhuis at: http://www.vinelandresearch.com/sites/default/files/grower_guide_pdf_final.pdf

See Table 18 (page 51) for information on scouting for key pests and biological control options and Table 20 (page 62) for insecticides labeled for vegetable transplants.

Aphids

Lifecycle: Several species of aphids can occur on vegetable transplants, but the most common are green peach, melon, foxglove and potato. Aphids are small, 1/16" in length, round, soft-bodied insects that vary in color from light green to pink or black. The green peach aphid is yellowish-green in summer; pink or yellowish in fall and spring. Winged forms are brown with a large dusky blotch on the abdomen. Melon aphids are greenish-yellow to very dark green with black mottling and short dark cornicles or "tailpipes" (tubular structures on the posterior part of the abdomen). Foxglove aphids are smaller than potato aphids but larger than melon and green peach aphids. The foxglove aphid is a shiny light yellowish green to dark green in color with a pear-shaped body. The only markings on the bodies of wingless adults are dark green patches at the base of the cornicles. The legs and antennae also have black markings. Foxglove aphids

cause more leaf distortion than green peach or melon aphids. Potato aphids have antennae longer than their bodies with long cylindrical tailpipes and are green or pink.

Aphids feed by inserting their piercing, sucking mouthparts into plant tissue and removing fluids. In greenhouses, aphids are usually females that produce live young called nymphs. Each female can produce 50 or more nymphs. Nymphs mature to adulthood and begin reproducing in as little as 7-10 days. Adults are usually wingless, but some will produce wings when populations reach outbreak levels. Large numbers of aphids will stunt and deform plants. In addition, aphids produce a sticky digestive by-product called honeydew and their white shed cast skins may be unsightly. Sometimes, these white cast skins are mistakenly identified as whiteflies. Honeydew can cover leaves and provide a food source for a superficial black fungus known as "sooty mold." Aphids are present on weeds and winged aphids may also enter the greenhouse through vents. Aphids can also transmit certain viruses.

Monitoring: Examine the foliage, along stems and new growth of key plants such as peppers, eggplants, cole crops and leafy greens to detect an early aphid infestation. Signs of aphid activity include shed white skins, shiny honeydew, curled new leaves, distorted growth and the presence of ants. Yellow sticky cards help detect the entrance of winged aphids into the greenhouse from outdoors. Yellow cards will not, however, allow you to monitor aphids within the crop, as most of the aphids will be wingless.

Caterpillars

Lifecycle: Caterpillars are the immature or larval stage of moths and butterflies (*Lepidoptera*). Most overwinter outdoors and may migrate into greenhouses especially during the summer and fall. Although they are not major pests of greenhouse crops, night flying moths may be attracted to lights near greenhouses. Female moths enter the greenhouse to lay their eggs on susceptible crops. Their life cycle consists of egg, larvae, pupa and adult. Females emit pheromones that attract males, and after mating, the females lay eggs that hatch into rapidly growing caterpillars. They may molt up to 5 times before entering a resting stage. Day flying butterflies, such as the imported cabbageworm, develop into a chrysalis as a resting stage and night flying moths develop into a pupal cocoon. Depending upon the species there may be from 1 to 3 or 4 generations a year. Cole crops are especially susceptible to damage from the imported cabbageworm, cabbage looper, diamondback moth and cross striped cabbageworm.

Monitoring: Visually inspect plants when adults are active. In greenhouses, pay close attention to plants near doors, vents and other openings, especially near weedy areas or near vegetable fields.

Fungus Gnats, Shore Flies, and Predatory or Beneficial Hunter Flies

Lifecycle: The damp, moist environment in greenhouses favors both fungus gnats and shore flies. Fungus gnat larvae are translucent, white and legless, about 1/4" long when mature, and have a shiny black head. The mosquito-like adult is about 1/8" long with long legs, a pair of clear wings and long antennae. There is a distinct "Y" vein on each wing. Fungus gnats are weak fliers and are frequently observed resting on pot media or running over the foliage or other surfaces. The larvae feed on fungi and decaying organic matter, and often

injure seedlings and plants. Larva feeding occurs on young, tender roots and in the stem at the base of the plant. This feeding injury provides an entry for disease pathogens. A female fungus gnat may lay up to 300 whitish eggs in clusters of 20 or more. The eggs are deposited on the surface or in the crevices of moist soil or potting media. Eggs hatch in about six days. Larvae feed for 12-14 days before changing into pupae. The pupal stage may last 5-6 days. Adults live up to ten days. The life cycle from egg to adult requires approximately 21-28 days depending on greenhouse temperatures.

Adult shore flies also occur in damp greenhouses. Shore flies are often misidentified as fungus gnats or hunter flies but they have a distinctly different appearance. The adult shore fly is about 1/8" long and has a robust body, very short antennae, shorter legs and dark wings with about five light spots. Adults may be seen resting on plant leaves. Larvae are off-white and do not have distinct head capsules that are characteristic of fungus gnat larvae. Shore flies do not injure plants through direct feeding, but can carry root rot pathogens from diseased to healthy plants. Their fecal spots or droppings can also be unsightly. To manage shore flies, control their food source, algae.

Adult hunter flies, a natural enemy (beneficial fly) are also found on sticky cards that may be mistaken for shore flies. Hunter flies can be distinguished from shore flies, by their size and color. Hunter flies are about twice as large as shore flies with wings that are uniformly clear and do not have light spots on their wings. Hunter flies are in the same family as common houseflies and are similar in appearance. Hunter flies may prey upon fungus gnats and shore flies.

Monitoring: To monitor for fungus gnat larvae, place raw potato chunks (with peel removed) on the soil surface. Larvae are attracted to the potato chunks and will congregate underneath. Check the potato chunks after 2 days for the larvae. Potato disks cut one inch in diameter and 0.5"-1" thick are effective. In addition, choose plants on each bench and inspect the soil surface and around the base of the plant including the stem just below the soil line. Record the location and the level of infestation. Badly infested plants should be removed as they serve as a source of infestation.

Adult fungus gnats can be monitored with yellow sticky cards placed at the base of the plant at the soil line. Weekly inspections of yellow sticky cards can detect the onset of an infestation, and continued recording of the number of adults per card per week can aid in evaluating the efficacy of control efforts.

Leafminers

Spinach leafminer (*Pegomya hyoscyami* Panzer) and beet leafminer (*Pegomya betae*) feed between the upper and lower epidermis of the leaf. Early damage is a slender, winding 'mine' or tunnel, but as the larva feeds and grows these may expand and become blotches on the leaves. Spinach and beet leafminers may cause damage on chard, beet, and spinach transplants.

Life Cycle: Adult spinach and beet leafminers are flies that overwinter as pupae in the soil and emerge in late-April and May. The two species are similar in behavior, appearance, plant hosts, and damage, but beet leafminer adults are slightly larger and darker, and beet leafminers prefer laying eggs on beet leaves. The small, gray adult flies lay small, oblong white eggs in clusters on the undersides of leaves. Eggs develop into pale, white maggots that damage the leaves. The larva burrows between the upper and lower epidermis of the leaf

and feeds, creating a slender, winding 'mine' or tunnel. This expands into large blotches of translucent, dead tissue across the leaf, with a white maggot inside. When fully grown, maggots usually drop into the soil to pupate, though they may also pupate inside the leaf. The entire life cycle is 30-40 days and there are three to four generations per season.

Monitoring: Look for the small, oblong, white eggs that are laid in neat clusters on the underside of the leaves. Inside the mines look for one or several pale, white maggots.

Mites

Two-spotted Spider Mites

Lifecycle: Two-spotted spider mites can be found on vegetable bedding plants. Adult females are approximately 1/50" long, and slightly orange in color. All mobile stages are able to pierce plant tissue with their mouthparts and remove plant fluids. Most spider mites are found on the underside of leaves. Feeding injury often gives the top leaf surfaces a mottled or speckled, dull appearance. Leaves then turn yellow and drop. Large populations produce visible webbing that can completely cover the leaves. Eggs are laid singly, up to 100 per female, during her 3-4 week life span. Eggs hatch into larvae in as few as 3 days. Following a brief larval stage, several nymphal stages occur before adults appear. Egg to adult cycle can be completed in 7-14 days depending upon temperature. Hot and dry conditions (80°F and 30-50% RH) favor spider mite development.

Monitoring: Check for mites by examining foliage. Adult spider mites are not found on sticky cards. Mites often develop as localized infestations on beans, tomatoes, or eggplants. Sample plants by turning over leaves and with a hands-free magnifier (Optivisor™) or hand lens, check for the presence of spider mites.

Broad Mites

Life Cycle: Broad mites are closely related to cyclamen mites. They can be distinguished from cyclamen mites by their egg stage. Eggs are covered with "bumps" that look like a row of diamonds. Eggs are best seen using a dissecting microscope. Adults and larvae are smaller than the cyclamen mites and walk rapidly on the underside of leaves. Broad mites can also attach themselves to whiteflies and use the whiteflies as a carrier for their dispersal. The development of broad mites is favored by high temperatures (70°-80°F and 80%-90% RH). Broad mites can complete their life cycle in as little as one week. Females lay from 30 to 75 eggs.

Monitoring: Broad mites can affect a number of ornamentals including gerbera daisy, New Guinea impatiens, salvia, ivy, verbena and zinnia. They may migrate to peppers or tomatoes. Look for characteristic damage including leaf edges curling downward. Terminal buds may be killed. As they feed, broad mites inject toxic saliva, which results in the characteristic twisted, distorted growth. Broad mite injury can be mistaken for herbicide injury, nutritional (boron or calcium) deficiencies or physiological disorders. Inspect the underside of the leaves for the mites and their eggs with a 20x hand lens or submit samples to a laboratory for diagnosis. Microscopic examinations are often helpful.

Cyclamen Mites

Life Cycle: The shiny, orange-tinted cyclamen mites prefer to hide in buds or deep within the flowers. Eggs are deposited

in moist places at the base of the plant. Cyclamen mites can complete their life cycle in 1-3 weeks. Females can live up to one month and can reproduce without mating. Cyclamen mite females lay 2-3 eggs per day for up to 2-3 weeks. Cyclamen mite eggs are oval, smooth and about one half the size of the adult female. Larvae hatch from the eggs in 3-7 days. The slow moving white larvae feed for 4-7 days. Cyclamen mites prefer high relative humidity (80-90% RH) and temperatures of 60°F. Cyclamen mites affect a number of ornamental bedding plants including dahlia, fuchsia, gerbera daisy, petunias and viola. They may migrate to peppers or tomatoes.

Monitoring: Cyclamen mites pierce tissue with their mouthparts and suck out cell contents. Look for signs of damage which may be concentrated near the buds or occur on the entire plant. Symptoms include inward curling of the leaves, puckering and crinkling. Pit-like depressions may develop. The mite is only 1/100th of an inch long. Examination under a microscope is often needed to confirm the presence of cyclamen mites.

Slugs

Life Cycle: Slugs are classified as mollusks and are covered with mucous-like slime that protects their bodies from desiccation. Slugs lay translucent pearl-shaped eggs in clusters of 20 to 100 in cool, moist locations such as in the soil or growing medium or underneath containers. Eggs hatch in less than 10 days at 50°F. Young slugs resemble adults but are lighter in color and smaller. They mature in 3-12 months and adults may live a year or more. Slugs contain both male and female organs and may alternate sexes at different times during adulthood.

Monitoring: Slugs vary in size from 3/4 to 1-1/2 inches in length. Their color ranges from pale yellow to lavender or purple. Slugs feed on a wide-range of greenhouse grown crops at night. They use their chewing mouthparts to create holes in leaves and stems. Feeding damage from slugs may be confused with caterpillars. However, slugs completely consume leaves and stems, whereas caterpillars may leave portions of stems or leaf veins. Slugs also leave shiny mucous-like slime trails.

Thrips

Lifecycle: The most injurious species is the western flower thrips (WFT). They often do considerable damage before they are discovered because thrips are small, multiply rapidly and feed in plant buds in which they can remain undetected. WFT also vector Tospoviruses. Feeding marks from the rasping mouthparts of thrips appear as white streaks on the leaves. Infested new growth may curl under and leaves are often deformed. Adult WFT are about 1/16" long, with narrow bodies and fringed wings. Females are reddish brown and males are light tan to yellow. The wingless immature larval stages are light yellow. Female thrips insert eggs (several hundred per female) into plant tissue. The tiny yellowish larvae molt twice and feed on plant fluids as they mature. Larvae drop off the plant into the soil and pass through two stages, after which adults emerge. The egg to adult lifecycle can be completed in 2-4 weeks depending upon greenhouse temperature. During warmer temperatures development is more rapid than at cooler temperatures.

Monitoring: Early detection of a thrips infestation is critical for effective management because populations are lower and it is

Table 20: Insecticides Labeled for Insects and Mites on Vegetable Transplants				
Insecticide	Target Pests	Labeled Crops	Comments	
acetamiprid (TriStar 8.5 SL) REI 12h, Group 4A	Aphids, beetles, caterpillars, fungus gnat larvae, leafminers, leafhoppers, plant bugs, thrips, whiteflies	Vegetable transplants	Contact insecticide with high absorption and upward systemic mobility.	
azadirachtin (Aza-Direct ^(®)), (AzaGuard ^(®)), (Azatin O ^(®)), (Molt X ^(®)), (Neemix 4.5 ^(®)) REI 4h; (Omazin 3% EC) REI 12 h	Aphids, beetles, caterpillars, fungus gnat larvae, leafminers, thrips, whiteflies and other insects (depending upon label)	Many vegetables (See specific labels)	Contact insecticide. Insect growth regulator for immature stages of insects. Repeat applications needed.	
azadirachtin & pyrethrins (Azer ^(®)) REI 12h, Group unknown & 3A	Aphids, beetles, caterpillars, fungus gnats, leafhoppers, leafminers, shore flies, thrips, whiteflies	Many different vegetables (see label)	Insect growth regulator and contact insecticide combined.	
Bacillus thuringiensis subsp. aizawai (Xentari ^(®) , Agree WG ^(®)) REI 4h; Group 11A	Certain caterpillars (see label)	Many vegetables (see labels)	Stomach poison that must be ingested to be active. Most effective against small, newly hatched larvae. Insects stop feeding and die 1 to 5 days later. Thorough spray coverage needed.	
Bacillus thuringiensis subsp. kurstaki (DiPel Pro DF ^(®)), (Javelin WG ^(®)), (Thuricide N/G ^(®)) REI 4h, Group 11A	Certain caterpillars (see labels)	Many vegetables (see labels)	Stomach poison that must be ingested to be active. Thorough coverage of all plant parts is important. Most effective against small, newly hatched larvae. Insects stop feeding and die 1 to 5 days later.	
Bacillus thuringiensis subsp. israelensis (Gnatrol WDG ^(®)) REI 4h, Group 11A	Fungus gnat larvae	Vegetable plants such as leafy and Cole crops, cucumbers, peppers, tomatoes and eggplants	Stomach poison that must be ingested to be active. Most effective against first instar larvae. Apply as soil drench. Larvae must ingest material to be killed.	
Beauveria bassiana ANT-03 (BioCeres WP ^(®)) REI 4 hr	Aphids, plant bugs, thrips, whiteflies	Many vegetables	Contact insecticide. Active ingredient is an insect-killing fungus.	
Beauveria bassiana GHA (BotaniGard ES) REI 4h (BotaniGard ZZWP) REI 4h (Mycotrol WPO, ES0 ^(®)) REI 4h	Aphids, leafhoppers, thrips, whiteflies (See labels for more information)	Many vegetables. Do not use ES formulation on tomato transplants.	Contact insecticides. Active ingredient is an insect killing fungus. Treat when insect populations are low. Repeated applications may be needed.	
Burkholderia A396 (Venerate XCOG) REI 4h	Aphids, caterpillars, mites, thrips, whiteflies	Many vegetables (see label)	Contact insecticide and stomach poison that disrupts insect exoskeleton interfering with molting.	
canola oil & pyrethrins (Pycana) ^(®) REI 12h	Aphids, beetles, caterpillars, fungus gnats, leafhoppers, leafminers, plant bugs, thrips, whiteflies	Many vegetables	Combination of a botanical oil and pyrethrins. See label for plant safety information.	
chlorfenapyr (Pjorn) REI 12h, Group 13	Caterpillars (including hornworms), broad mites, spider mites, thrips	Tomato, tomatillo, ground cherry, peppers, eggplant. Do not use on tomato varieties with a diameter of less than one inch when mature.	Insecticide/miticide with contact and translaminar activity. Active on larvae and nymphs of spider mites and thrips.	
chlorfenapyr (Pjorn TR) REI 12h, Group 13	Fungus gnat adults, mites, thrips	Greenhouse fruiting vegetables	Contact insecticide/miticide with translaminar and stomach poison activity.	
Chromobacterium subsitigae PRAA4-1 (Grandveo GC ^(®)) REI 4h	Aphids, beetles, caterpillars, leafhoppers, plant bugs, mites, thrips, whiteflies (depending upon crop, see label)	Many vegetables (see label)	Contact biological insecticide for young immature stages. See label for plant safety information.	
cyromazine (Citation) REI 12h, Group 17	Dipterous leafminers (<i>Liriomyza</i> species), fungus gnat and shore fly larvae	Vegetable transplants grown for consumer use (see label for specific types)	Insect growth regulator. Applied to growing medium to control fungus gnat and shore fly larvae. Available in water-soluble packets.	
dinotefuran (Safari 20 SG) REI 12h, Group 4A	Aphids, leafminers, thrips (suppression), whiteflies	Many vegetable transplants grown in enclosed structures.	Contact and systemic insecticide for foliar application.	
flupyradifurone (Altus) REI 12h, Group 4D	Aphids, leafhoppers, whiteflies	Many including cucurbits, fruiting and leafy vegetables.	Systemic insecticide with translaminar activity. See label for precautions on cucurbits. Do not make more than 1 application per crop prior to transplant. Do not rotate with Group 4A products.	
hexythiazox (Hexygon) REI 12h, Group 10A	Two-spotted spider mites	Pepper, eggplant, tomato transplants	Ovicide (egg-killing) activity. Most active on eggs and immature (larvae and nymphs) stages. Available in water-soluble packets. Use only once per crop cycle.	
mineral oil (Organic JMS Stylet Oil ^(®)) REI 4 h	Leafhoppers, leafminers, mites, whiteflies	Many vegetables	Contact insecticide/miticide. Foliar injury may occur if applied during humid conditions. See label for plant safety information.	
mineral oil (SuffOil-X ^(®)) REI 4 h	Aphids, leafhoppers, leafminers, mites, thrips, whiteflies	Many vegetables	Contact insecticide/miticide. Foliar injury may occur if applied during humid conditions. See label for plant safety information.	
mineral oil (Ultra-Pure Oil) REI 4 h	Aphids, leafhoppers, leafminers, mites, thrips, whiteflies	Greenhouse vegetables	Contact insecticide/miticide. Foliar injury may occur if applied during humid conditions. See label for plant safety information.	

Table 20: Insecticides Labeled for Insects and Mites on Vegetable Transplants (continued)

Insecticide	Target Pests	Labeled Crops	Comments
imidacloprid (Marathon II) REI 12h, Group 4A	Aphids, fungus gnat larvae, leafhoppers, leafminers, thrips (suppression), mealybugs, whiteflies	Vegetable bedding plants intended for resale only (See labels for specific types)	Contact, systemic and translaminar insecticide. Do not rotate with other products in Group 4A.
insecticidal soap potassium salts of fatty acids (Kopa Insecticidal Soap) ⁽⁰⁵⁾ REI 12 h	Aphids, mites, plant bugs, whiteflies	Many vegetables	Contact insecticide/miticide. Short residual activity. See label for plant safety information.
insecticidal soap Potassium salts of fatty acids (M-Pede) ⁽⁰⁵⁾ , REI 12h	Aphids, broad mites, leafminers, leafhoppers, plant bugs, spider mites, thrips, whiteflies	Many vegetables including bulb, Cole, leafy, fruiting and cucurbit types	Contact insecticide/miticide. Short residual activity. Refer to label for information on plant safety. Can be tank mixed with other products to increase efficacy.
iron phosphate (Sluggo) ⁽⁰⁵⁾ REI 0h	Slugs and snails	Many vegetables (see label)	Bait. Ingestion causes the slugs and snails to cease feeding, become less mobile and begin to die in 3 to 6 days. Best applied in the evening. Can be used around pets and wildlife.
iron phosphate & spinosad (Brandt Antixx Plus Insect, Slug and Snail Bait) ⁽⁰⁵⁾ REI 4 h	Ants, cutworms, slugs, snails	Many vegetables	Bait.
iron phosphate & spinosad (Bug-N-Sluggo) ⁽⁰⁵⁾ REI 4h	Cutworms, slugs, snails	Many vegetables (see label)	Bait. Refer to label for application rates
Isaria fumosorosea (Ancora) ⁽⁰³⁾ (PFR-37 20% WDGOG) REI 4h	Aphids, leafminers, plant bugs, spider mites, thrips, whiteflies. Drench application to thrips pupae.	Vegetables grown in greenhouse	Microbial insecticides that work by contact. Apply when relative humidity is >75% with moderate temperatures. Product needs to be premixed to avoid clogging. See technical sheet and labels.
neem oil (Triact 70) ⁽⁰⁵⁾ REI 4h	Aphids, broad mites, leafhoppers, spider mites, thrips (suppression), whiteflies	Many vegetable transplants (see label)	Contact insecticide/miticide. Thorough coverage of all plant parts is important. Refer to label for information on plant safety.
parasitic nematodes (<i>Steinernema carpocapsae</i>) (Millenium) Exempt from REI	Shore fly larvae	Greenhouse crops	Apply to moist growing media (65° to 86°F) during cloudy, overcast conditions. Remove screens and filters from sprayers and injectors. Repeat applications needed in areas where algae is growing.
parasitic nematodes (<i>Steinernema feltiae</i>) (NemaShield, Nemasys, Scanmask) Exempt from REI	Fungus gnat larvae, thrips pupae in growing media	Greenhouse vegetables	Apply to moist growing media (60-80°F) during cloudy, overcast conditions. Remove screens and filters from sprayers and injectors.
pymetrozine (Endeavor) REI 12 hr, Group 9B	Aphids, whiteflies	Many vegetables	Insecticide with systemic and translaminar activity. See supplemental label for use on vegetable transplants grown for sale to consumers.
pyrethrins (PyGanic EC 1.4 I/OG, PyGanic EC 5.0 I) ⁽⁰⁵⁾ (PyGanic Specialty) ⁽⁰⁵⁾ REI 12h, Group 3A	Aphids, caterpillars, fungus gnat adults, leafhoppers, thrips, whiteflies	Many including bulb, leafy, Cole, fruiting and cucurbit vegetables	Contact insecticides. Provides rapid knockdown of pests.
pyrethrins & Beauveria bassiana GHA (BotaniGard Maxx) REI 12h Group 3A and unknown Group 3A	Aphids, beetles, caterpillars, fungus gnats, leafhoppers, plant bugs, spider mites, thrips, whiteflies	Many vegetables	Contact insecticides. Natural pyrethrum combined with insect killing fungus. Do not apply when beneficial insects are present.
pyrethrins plus PBO (Pyrethrum TR) REI 12h, Group 3A	Aphids, beetles, fungus gnat adults, leafhoppers, plant bugs, shore flies, thrips, whiteflies	Many vegetables (see label)	Contact insecticide. See label for specific directions for placement and use for successful application.
pyriproxyfen (Distance Insect Growth Regulator) REI 12h, Group 7C	Foliar spray for whiteflies and aphids (suppression). Apply as a spranch (growing media surface spray) or drench for fungus gnat and shore fly larvae	Indoor-grown fruiting vegetables	Insect growth regulator. See label for plant safety information.
spirotriflamut (Kontos) REI 24h, Group 23	Aphids (suppression), broad mites, cyclamen mites, leafhoppers, spider mites, thrips immatures, whiteflies	Vegetable transplants for resale (see label for specific types)	Systemic insecticide for foliar and drench application. See label for plant safety information.
sulfur (Microthiol Dispers) ⁽⁰⁵⁾ REI 24 h	Broad mites (pepper), spider mites	Many vegetables	Contact miticide/fungicide.
thiamethoxam (Flagship 25 WG) REI 12h, Group 4A	Fruiting vegetables: aphids, flea beetles, leafhoppers, whiteflies Cucurbit vegetables: aphids, flea beetles, cucumber beetles (suppression), leafminers (suppression), whiteflies	Foliar application to vegetable plants grown for resale to consumers. See label for specific types of fruiting and cucurbit vegetables.	Systemic insecticide for foliar or drench application for transplants only.

The symbol ⁽⁰⁵⁾ indicates a pesticide is listed by the Organic Materials Review Institute (OMRI) as approved for use in certified organic production. This information is supplied with the understanding that no discrimination is intended and no endorsement implied. Due to constantly changing regulations, we assume no liability for suggestions. If any information in these tables is inconsistent with the label, follow the label.

easier to obtain good spray coverage when plant canopies are small. Symptoms of their feeding are often not noticed until the damage has occurred. Eggplant, tomatoes, leafy greens and peppers are prone to thrips infestations. Yellow sticky cards, key plants and indicator plants can be used to detect the onset of an infestation. Yellow sticky cards should be placed just above the crop canopy, and near doors, vents and over thrips-sensitive cultivars to monitor their movement. The light to medium-blue sticky cards may catch more thrips (and shore flies) than yellow ones. However, it is more practical to use yellow cards for general pest monitoring to attract fungus gnats, whiteflies and winged aphids. The number of thrips per card should be recorded and graphed weekly to monitor population levels and movement in or out of the greenhouse. See section on key plants and indicator plants, page 58, for more monitoring information.

Whiteflies

Lifecycle: The sweet potato (a.k.a. silverleaf) whitefly *B* biotype (*Bemisia argentifolii*) and greenhouse whitefly (*Trialeurodes vaporariorum*) may infest vegetable bedding plants. However, greenhouse whitefly is the most common species in New England. Both adult and immature whiteflies have piercing sucking mouthparts to remove fluids. Like aphids, they also produce honeydew that results in sooty mold fungus. Winged adult whiteflies are 1/16" in length, and are usually found on the youngest, most tender leaves. Females may lay from 150-300 eggs, which hatch into first-instar nymphs in about a week. These "crawlers" move for a short distance before settling down to feed. After three molts, a pupal stage is formed, and adults emerge in about six days. Whiteflies complete their egg to adult cycle in 21-36 days, depending upon greenhouse temperatures.

Monitoring: To monitor whiteflies, check susceptible plants, such as tomatoes, at ten locations in an area of 1,000 square feet, examining plants on each side of the aisle. Look on the undersides of one or two leaves per plant, for nymphs, pupa and adults. Yellow sticky traps can also be used to detect adult whiteflies once populations have reached higher densities. Begin treatments as soon as the first sign of infestation is noted.

TRANSPLANT WEED MANAGEMENT

In greenhouses, weeds are primary hosts of aphids, whiteflies, thrips, mites, slugs and diseases. Low growing weeds help maintain moist conditions, a favorable environment for fungus gnats and shore flies. Many common greenhouse weeds such as chickweed, oxalis, bittercress, jewelweed, dandelion and ground ivy can become infected with Tosspoviruses including impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV), though they show few symptoms. Thrips can then vector the virus to susceptible vegetable crops. Weeds can also carry other plant damaging viruses that are vectored by aphids. Integrated weed management includes sanitation and physical barriers, along with direct controls, such as hand weeding and selective use of postemergence herbicides.

The use of a physical barrier such as a weed block fabric is an effective method to limit weed establishment on greenhouse floors. The weed fabric should be left bare so it can be easily swept. Covering the weed fabric with gravel makes it difficult to remove any spilled potting media, which

provides an ideal environment for weed growth. Regularly pull any escaped weeds before they go to seed. Repair tears in the weed block fabric.

Overall, it is best to avoid herbicide use in a greenhouse when plants are present. If herbicides are used, read and follow all the information below and consult labels. If the label does not say that it can be used in the greenhouse, then don't use it. Herbicides that are not considered volatile in field situations can cause significant injury through vapor movement in warm and enclosed structures.

Few herbicides are labeled for use in a greenhouse due to the potential for severe crop injury or death to desirable plants. This injury may occur in a number of ways including: 1) spray drift if fans are operating at the time of application; and 2) volatilization (changing from a liquid to a gas). Herbicide vapors are then easily trapped within an enclosed greenhouse and can injure plant foliage. Always be sure the herbicide selected is labeled for use in the greenhouse. Carefully follow all label instructions and precautions. It is the applicator's responsibility to read and follow all label directions. Use a dedicated sprayer that is clearly labeled for herbicide use only.

Avoid use of preemergence herbicides in the greenhouse! Preemergence herbicides are applied to soil to prevent the emergence of seedlings. They can persist for many months and in some cases over a year. Preemergence herbicides can continue to vaporize in the greenhouse, causing significant damage to young transplants. Only one preemergence herbicide, indaziflam (Marengo) is labeled for greenhouse use on greenhouse floors in an EMPTY greenhouse.

Postemergence herbicides are applied after the weeds have emerged. Several postemergence herbicides can be used under greenhouse benches and on the floors. Contact herbicides are best applied to small seedlings. Large weeds will be burned but not killed.

Herbicides for Use in Greenhouses

Ammonium nonanoate (Axxe^{OG}): REI 4h. Non-selective, contact, postemergence herbicide. Avoid contact with desirable vegetation.

Glyphosate (Roundup Pro, Roundup Pro Concentrate): REI 4h. Non-selective postemergence herbicides. Translocated/systemic. For use in an empty greenhouse between crops and outside greenhouses.

Pelargonic acid & related fatty acids (Scythe): REI 12h. Non-selective, postemergence, contact herbicide. Cool or cloudy weather may slow down activity. Provides no residual weed control but leaves a strong odor. For use when crops are in the greenhouse.

The symbol ^{OG} indicates a pesticide is listed by the Organic Materials Review Institute (OMRI) as approved for use in certified organic production.

Weed Control Outside of Greenhouses

In addition to mowing, herbicides may also be used outside of greenhouses. Before spraying weeds around the greenhouse with any herbicide, close windows and vents to prevent spray drift from entering the greenhouse. Avoid using auxin-type herbicides, such as those labeled for broadleaf weed control in turf or brush killers, or herbicides with high volatility near greenhouses. Select herbicides with low volatility.

Integrated Pest Management

Integrated Pest Management (IPM) is the coordinated use of pest and environmental information to design and implement pest control methods that are economically, environmentally and socially sound. IPM promotes prevention over remediation and integrates multiple control strategies to achieve long-term pest management solutions.

IPM is a decision-making strategy based in scheduled, systematic observation and documentation of crop health and environmental conditions. Preventative measures are built into the production system in anticipation of potential issues. Actions are taken in response to established thresholds, and results are documented.

- **Accurate pest identification** is important; misidentification of pests is a common cause of pest control failure and crop damage. See the Diagnostics for Plant Problems, page 66, section and Northeast Vegetable & Strawberry Pest Identification Guide for help. There are also many excellent on-line resources.
 - **Biology and life-cycle** of pests reveal vulnerable stages for successful control measures. Detailed, pest-specific information is available in fact sheets on IPM web sites or publications listed in the References and Resources section. See also specific pest listings in this Guide.
 - **Scouting** is systematic, regular inspection of crops to quantify pest populations or crop injury. Scouting techniques vary depending upon the type of pests (weed, insect, disease or other) involved. Details are available in pest and crop-specific IPM fact sheets and manuals, and in pest listings in this Guide.
 - **Monitoring** weather trends and trap catches can be used to assess or predict current or future pest problems and help to prevent crop damage. Equipment and procedures vary by pest (for details see references mentioned above). Disease forecasting and insect development models for local conditions in many states can also be accessed at www.NEWA.cornell.edu.
 - **Action thresholds.** When systematic scouting documents pest numbers in excess of research-based thresholds, active control measures are recommended to prevent or minimize economic loss. Such results may be expressed, for example, as 7 moths/week, 2 weeds/foot of row, or 20% defoliation, or as a rating for weather conditions like “15 Disease Severity Units.” Some thresholds are given for pests in the individual crop sections in this manual and others vary by state or region. Contact your state’s Extension IPM personnel for local action thresholds.
 - **Regular record-keeping.** Good records help determine which pest control strategies are working and where improvements should be made in the future. Try to keep track of scouting results, crop conditions and control procedures all season.
- Preventative and curative control methods are built into an IPM management plan for each pest, crop and farm. Pesticides are used when additional control measures beyond the following methods are required.
- **Cultural controls** are modifications of the crop production systems that create unsuitable conditions for pests. Examples include: appropriate site selection; crop rotation modification of planting times or spacing; precision water and nutrient management for better crop health; weed control to improve air circulation; subsoiling to improve drainage; sanitization of machinery between fields; and the use of cover and smother crops.
 - **Mechanical and physical controls** consist of using supplies, equipment, or some factor, such as temperature, humidity or light, to disrupt pest life cycles and/or suppress populations. Mechanical and physical controls function by cutting, crushing, burying or excluding pests with implements and barriers, or by heating, cooling, drying, wetting, or regulating light in some way. Some examples include: the use of hot-water-treated seed; plowing to bury infected crop residue; cultivation or flaming for weed control; plastic or organic mulches for weed suppression; row covers to accelerate crop growth and exclude pests; greenhouse ventilation; washing; cold storage; and roguing infected plants.
 - **Breeding for resistance** is a process of selecting for crop varieties that are resistant or tolerant to pathogenic microorganisms. There has also been breeding for insect and nematode resistance. Some breeding has been done to favor growth characteristics that enable plants to withstand disease pressure (such as rapid emergence, heat or cold tolerance, canopy or leaf traits). Recombinant DNA technology (“genetic modification”) has been used in a few vegetable crops to achieve resistance by incorporating traits from non-related organisms; examples are virus resistance in summer squash and caterpillar resistance in sweet corn (through expression of the *Bt* protein toxin in plant tissues). At this time, these are the only genetically modified vegetables available for market production.
 - **Biological control** is the use of naturally occurring or introduced beneficial organisms to control or suppress pest populations. Biological control agents come in all shapes and forms including: insects, mites, spiders, nematodes, fungi, bacteria, viruses, protozoa and plants. In the broadest interpretation, they would include things like microbial pesticides and the use of trap crops. Common examples are parasitic wasps, entomophagus and competitive fungi and bacteria, predacious bugs, beetles and spiders. Natural enemies of pests exist everywhere in nature and should be conserved whenever possible. Many biocontrol organisms can be purchased for use in the greenhouse or for specific crops.

- **Pesticides** should be used in conjunction with the control measures previously mentioned and only when pest population densities will cause economic damage, or when environmental conditions favor disease. Selective insecticides are products that primarily target the pest(s) you wish to control, with few or no detrimental effects on most beneficial organisms. They may also have other attributes making them less harmful to the user and the environment and may be lumped into a larger category of Biorational pesticides (see Biorational and Organic Pesticides, page 74). If the use of a pesticide is required, choose a selective product or another biorational pesticide if possible. Selective insecticides usually spare biological control agents, reduce the risk of secondary pest outbreaks, reduce the impact on the environment, improve farm safety, and minimize the number of applications needed. Broad-spectrum insecticides usually kill many different kinds of pests and beneficial organisms. The use of broad-spectrum insecticides can often lead to resurgence of primary pest populations due to a lack of natural controls, or to secondary pest outbreaks and additional applications. Broad-spectrum insecticides should only be used if no other viable options exist to manage the pest. Proper pesticide application and resistance management techniques should be used to maximize the effectiveness and preserve the useful life of the available products.

Much of the space in this publication is dedicated to lists of pesticide options for weeds, insects and diseases on specific commodities. Effective pest management involves much more than using pesticides. Always review the summary paragraph(s) under each pest listing for preventative pest management methods and specific decision-making techniques before reaching for a pesticide. For detailed information on IPM, see the References and Resources section, or visit your local Extension System's IPM web site.

Abstaining from use of pesticides. Some growers choose to completely forgo the use of any kind of pesticides, be they conventional, biorational, or certifiably organic. While this strategy avoids possible detrimental effects to native natural enemies of pests and can save money on equipment and materials, it can lead to the buildup of very high populations of certain key pest species and disease inoculum. It may also affect neighboring farms by providing a sanctuary for local pest populations.

DIAGNOSTICS FOR PLANT PROBLEMS

Correct diagnosis of a problem and correct identification of the pest (insect, disease, abiotic factor, nutrition, etc.) causing the problem are key to successful crop management and profitability. Below is a list of laboratories that offer disease diagnostics on a fee-for-service basis. When submitting a sample, remember to specify whether you are looking for insect, disease, or weed (or other) identification in case more than one organism and/or symptom is present on your sample. Also, provide as complete a description of the problem as possible including crop, symptoms, distribution within field or greenhouse, and unique characteristics of the location. Commercial growers will receive different recommendations than home gardeners. Please indicate if you are an organic grower. In general, virus

screening is limited to a small group of common viruses; further analysis is referred to specialized laboratories. Contact your local lab or your state Extension Vegetable Specialist for more information.

In order to submit a sample for diagnosis, some basic preparation instructions should be followed.

These include:

- Collect specimens that show a range of symptoms (i.e., from healthy to seriously affected), usually collected from the margin of the affected area. Avoid specimens that are completely dead or decayed as they are not diagnostically useful.
- Fill out the sample submission form (provided by lab). This is very important. Without detailed information about the problem, a correct diagnosis is very difficult.
- Pack specimens in dry paper and place in a plastic bag (never pack with wet paper towels or add water).
- Mail specimen and submission form using same-day or overnight delivery, or deliver specimen personally the same day. If this is not possible, place in a refrigerator and mail or deliver the following day. Specimens should come to the diagnostic labs early in the week to avoid problems with weekend holdovers.

Plant Diagnostic Clinics of New England

(D = plant disease identification, I = insect identification, N = nematode analysis, W = weed identification)

Connecticut

UConn Home & Garden Education Center (D,I,N,W)
Ratcliffe Hicks Building, Room 4
1380 Storrs Road, Unit 4115
Storrs, CT 06269-4115
(toll free) 1-877-486-6271
<https://plant.lab.uconn.edu/>

Cost: \$15

The Plant Disease Information Office (D,I,N, W)
The Connecticut Agricultural Experiment Station
123 Huntington Street, P.O. Box 1106
New Haven, CT 06504
(203) 974-8601; (877)855-2237 toll-free outside New Haven area
www.ct.gov/caes

Cost: free

Maine

Plant Disease Diagnostic Lab (D,I)
Pest Management Unit
17 Godfrey Drive
Orono, ME 04473-3692
1-800-287-0279 (within Maine) or (207) 581-3883 (outside Maine)
fax: (207)581-3881
www.extension.umaine.edu/ipm/ipddl Cost: free to Maine residents
(except for garlic nematode testing)

Massachusetts

Plant Disease Diagnostic Laboratory (D,I,N,W)
UMass Extension Plant Diagnostic Lab
#3 French Hall, 230 Stockbridge Road
Amherst, MA 01003
(413) 545-3208 fax: (413) 545-4385
<http://ag.umass.edu/diagnostics>

Cost: \$50.00

Integrated Pest Management

New Hampshire

The Plant Diagnostic Lab (D,I,W)
UNH Plant Diagnostic Lab
38 Academic Way, G37 Spaulding Hall
Durham, NH 03824
(603) 862-3200 fax: (603) 862-2717
<https://extension.unh.edu/programs/plant-disease-diagnosis-services>
Cost: \$20.00

Rhode Island

University of Rhode Island Cooperative Extension Education Center (D,I,W)
URI Plant Protection Clinic
CE Education Center
3 East Alumni Avenue
Kingston, RI 02881
(401) 874-2900 fax: (401) 874-2259
<https://web.uri.edu/coopect/ppc/>
Cost: \$10

Vermont

University of Vermont Plant Diagnostic Clinic (D,I,W)
201 Jeffords Hall,
63 Carrigan Drive
University of Vermont
Burlington, VT 05405
(802) 656-0493 fax: (802) 656-4656
<https://www.uvm.edu/extension/pdc> Cost: \$15 Vermont residents only

PESTICIDE SAFETY AND USE

Who can apply pesticides

Except in the state of Maine, farmers do not need a license to apply general use pesticides and a pesticide license is only required when using restricted use pesticides. Also, workers who help someone who is licensed or certified to apply restricted-use materials may also need a license to assist. Usually, commercial applicators follow a different set of rules that are more restrictive. It is important to check with your state lead agency to determine what is appropriate in your state. **Please note that the requirements of the EPA Worker Protection Standards (WPS) must still be followed regardless of whether a pesticide license or certification is required.** See the section below on WPS. As of this printing, the following are contacts in each state who can provide information on specific requirements for pesticide licenses and certification when necessary. If more information is needed, go directly to the web site for each state.

Connecticut: 860-424-3369, <http://www.ct.gov/deep/cwp/view.asp?A=2710&Q=324260>

Maine: 207-287-2731, <http://maine.gov/agriculture/pesticides/cert/questions.htm>

Massachusetts: 617-626-1784, <http://www.mass.gov/eea/agencies/agr/pesticides/>

New Hampshire: 603-271-3640, <http://agriculture.nh.gov/divisions/pesticide-control/index.htm>

Rhode Island: 401-222-4700, <http://www.dem.ri.gov/programs/agriculture/pesticides-regulatory.php>

Vermont: 802-828-2431, <https://agriculture.vermont.gov/public-health-agricultural-resource-management-division/pesticide-programs>

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Warning! Pesticides are poisonous. Read and follow all directions and safety precautions on labels. Handle carefully and store in original labeled containers out of reach of children, pets and livestock. Do not use concentrations greater than stated on the label. Do not apply more pesticide per acre or more frequently than the fewest number of days between applications recommended by the label. Remember that the pesticide label is a legal document. If you do not follow the label directions implicitly, you could lose your applicator's license or be fined by the State Lead Agency (SLA).

Pesticide Registration

Pesticides require both federal and state registration. Pesticides in this publication have been reviewed for federal registration status and are current at the time of publication. State registration status has been reviewed for most products, but state registrations are renewed annually and may be subject to change. Each New England state maintains a registration database, which can be found at the following websites:

Maine

Maine Board of Pesticides Control
http://npirspublic.ceris.purdue.edu/state/state_menu.aspx?state=ME
Searchable database

New Hampshire

Division of Pesticide Control
<http://agriculture.nh.gov/divisions/pesticide-control/registration.htm>
Contact Director of Division of Pesticide Control for information

Vermont

Vermont Agency of Agriculture, Food, and Markets
<http://www.kellysolutions.com/vt>
Searchable database

Massachusetts

Massachusetts Pesticide Product Registration Information
<http://www.kellysolutions.com/ma>
Searchable database

Connecticut

Connecticut Department of Energy and Environmental Protection
<http://www.kellysolutions.com/ct>
Searchable database

Rhode Island

Department of Environmental Management
http://npirspublic.ceris.purdue.edu/state/state_menu.aspx?state=RI
Searchable Database
Select 'Registered Pesticides' link for list

Understanding Pesticide Labels

A pesticide is referred to: (1) by a common name, which is also the name of the active ingredient (AI) or (2) by a trade or brand name (trade names are capitalized in this guide). Trade names are used in the guide for identification only; no product endorsement is implied, nor is discrimination intended against similar materials.

Labels are for your protection and information: Look for the percentage (by weight) or amount of material in the formulation. Compare costs of two similar products on the basis of effectiveness, the amount of actual pesticide contained and the quantity of the formulations needed/acre.

Labeled Formulations: The examples of pesticide products that are listed under each crop within this publication give

only one formulation and one trade name. Often there are other formulations and trade names with the same active ingredient. Growers should be aware of other formulations and products. Consult the tables in Disease, Insect and Weed Management Sections (Tables 25, 26, and 27) for lists of formulations and products. The rates to be applied are on the label.

- Emulsifiable concentrates (EC) are less troublesome to spray equipment than wettable powders (WP). The water-based flowable concentrates and wettable powders are less likely to cause plant injury than oil-based concentrates of similar materials.
- Wettable powders/suspendable powders (WP) are less likely than ECs to cause injury to sensitive plants or to cause trouble when mixed with fungicides or other pesticides.
- Dry flowables (DF) are similar to wettable powders in their formulation but are pelletized to minimize dust.
- Flowables (F) are liquid formulations with similar properties to latex paint. Clean equipment immediately after use.

NOTE: There may be several products registered with the same active ingredient. Each label is different, and some crops may be listed on some labels but not on others. Always be certain the crop is listed on the product label before ordering or using the product.

Restricted-Use Pesticides: In accordance with federal and state pesticide regulations, those pesticides that are highly toxic and those that persist and accumulate in the environment are placed on a restricted-use list and shall be sold and used only by certified applicators. For information about training for certified applicators contact your Extension Specialist or the offices listed above. In some instances, states may require additional permits for certain pesticide users.

Control of target pest not on the label: Always be certain the crop is on the label before using a pesticide on that crop. Target pests not listed on the label may not be effectively controlled by that product.

Tank mixture and aerial application: Check the label and consult your state pesticide regulatory agency.

To avoid illegal residues: Adhere strictly to preharvest intervals. Accurately calibrate your equipment; never exceed label recommendations. Prevent drift to adjacent properties or crops, or contamination of bodies of water. The applicator is held responsible for problems caused by drift or contamination. High-volume, low-pressure, ground applications cause less drift than low-volume, high-pressure, air-blast, ground applications, aerial applications or dust.

Disposal of pesticides: Read label. For current instructions on regulations and guidelines pertaining to the disposal of chemicals, contact your State Lead Agency (SLA) for pesticide regulation located in either the state Department of Agriculture or state Department of Environmental Protection. The Pesticide Stewardship Alliance (TPSA) has a pesticide disposal database with resources for each state. Visit their website at <https://tpsalliance.org/resources/state-disposal-map/>. Triple rinse empty containers; dispose of them carefully and properly.

It is the responsibility of the user to read the label and be sure that the material selected is labeled for the proposed use. Similar pesticide products may not have the same crop uses.

Pesticide Toxicity

All pesticides are poisonous. However, some are more toxic than others. The toxicity of the pesticide is usually stated in the precaution label. For example, a skull and crossbones figure and the signal word “Danger” are always found on the label of highly toxic (Toxicity Class I) materials. Those of medium toxicity (Toxicity Class II) carry the signal word “Warning”. The least toxic materials (Toxicity Class III) have the signal word “Caution”. The toxicity of a pesticide is expressed in terms of oral and dermal LD₅₀. LD₅₀ (lethal dose 50) is the dosage of active ingredient that kills 50% of test animals (usually rats or rabbits) with a single application of the pure pesticide for a given weight of the animal (mg/kg of body weight). The lower the LD₅₀ value, the more toxic the material. Oral LD₅₀ is the measure of the toxicity of pure active ingredient when administered internally to test animals. Dermal LD₅₀ is the measure of the toxicity of pure active ingredient applied to the skin of test animals. Generally, an oral application is more toxic than a dermal one.

The Worker Protection Standard and Who Must Comply

Pesticides can be useful tools for farmers. They can also be deadly. Exposure to pesticides can cause physical harm, debilitation, and even death. Not only applicators are at risk. Family members and workers can also be harmed due to improper storage and use of pesticides.

For this reason, the EPA has developed the **Agricultural Worker Protection Standard (WPS) for Pesticides** (US EPA regulation, 40 CFR Part 170). The WPS applies to all pesticides that are used in the production of agricultural plants on farms, forests, nurseries, and greenhouses. This includes general use pesticides including those allowed in organic production (OMRI-approved), as well as restricted-use pesticides. Also, even if a pesticide license is not required, employees and handlers must still receive education in and comply with the WPS.

The WPS requires the owner or employer to take steps to reduce the risk of pesticide-related illness and injury: 1) if pesticides are used on the farm or 2) workers or pesticide handlers are employed who may be exposed to such pesticides.

You will know a pesticide product is covered by the WPS if you see the following statement in the “Directions for Use” section of the pesticide labeling:

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment, notification of workers, and restricted-entry intervals.

The primary WPS resource is the How to Comply manual (<http://pesticideresources.org/wps/htc/index.html>), developed

by EPA. The manual is available from your State Lead Agency (SLA), pesticide education office of the Cooperative Extension Service, the EPA Region 1 office and EPA's National Agricultural Compliance Assistance Center. Every agricultural producer should have a copy of the EPA How to Comply manual at <https://www.epa.gov/pesticide-worker-safety/pesticide-worker-protection-standard-how-comply-manual>.

Key Elements of the Worker Protection Standard

The following is a brief summary of the major elements of the WPS. Each of these categories is described in greater detail in the EPA How to Comply manual. Producers should refer to the How to Comply manual for complete details and explanations of the requirements of the Worker Protection Standard.

Information and Education. To ensure employees will be informed about exposure to pesticides, the WPS requires:

- Annual pesticide safety training for workers and handlers,
- Pesticide safety poster to be displayed for workers and handlers
- Access to labels and material safety data sheets for pesticide handlers and early-entry workers
- Access to specific information in a centrally-located Application List of pesticide treatments on the establishment

Protection. To ensure employees will be protected from exposures to pesticides, the WPS requires employers to:

- Prohibit handlers from applying a pesticide in a way that will expose workers or other persons
- Exclude workers from areas being treated with pesticides
- Exclude workers from areas that remain under a restricted entry interval (REI) with narrow exceptions
- Protect early-entry workers who are doing permitted tasks in treated areas during an REI requirements include special instructions and duties related to correct use of Personal Protective Equipment (PPE)
- Notify workers about treated areas so they can avoid inadvertent exposures
- Protect handlers during handling tasks. Requirements include monitoring while handling highly toxic pesticides and duties related to correct use of PPE.

Mitigation. To mitigate exposures that employees receive, the WPS requires:

- Decontamination sites that provide handlers and workers an ample supply of water, soap and towels for routine washing and emergency decontamination,
- Emergency assistance that provides transportation to a medical care facility if an agricultural worker or handler may have been poisoned or injured by a pesticide and providing information about the pesticide(s) to which the person may have been exposed.

Agricultural Owner Exemptions. Even if you are the owner of the farm, forest, nursery, or greenhouse and you or members of your family do all the work there, you are a "WPS employer."

You must comply with SOME of the WPS requirements, such as adhering to restricted entry intervals, personal protective equipment (PPE) and ALL the specific requirements listed in the pesticide labeling.

If you hire commercial handlers, certain information must be given from you (the operator) to the commercial handler employer.

- Specific location and description of any areas that may be treated with a pesticide or be under an REI while handler is there, or that the commercial handlers may be in (or walk within 1/4 mile of),
- Restrictions on entering those areas.

Crop Advisors. The WPS requires employers to provide certain protections to their employees who are working as crop advisors. Examples of crop advisors are crop consultants, scouts, and integrated pest management monitors. An independent or commercial crop advisor is any person working as a crop advisor who is employed (including self-employed) by anyone other than the agricultural establishment on which the work is being done. Certain provisions of the WPS apply to crop advisors depending on when the advisor is on the farm and when the pesticide has been applied.

Commercial Handlers. Employers of commercial handlers must make sure that their customer the operator of the farm, forest, nursery or greenhouse, knows certain information such as: specific location and description of the area treated with the pesticide, time and date pesticide is to be applied, product name, EPA registration number, active ingredient(s), REI for the pesticide, whether the labeling requires treated area posting and oral notification and any other specific requirements on the pesticide labeling concerning protection of workers and other persons during or after application.

For more information on the WPS, contact your Cooperative Extension Pesticide Safety Education Coordinator, SLA or EPA Region 1 office, or visit <https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps>

Pesticide Storage

Pesticides should always be stored in their original containers and kept tightly closed. For the protection of others, especially firefighters, the storage area should be posted as Pesticide Storage and kept securely locked.

Herbicides, especially hormone-like weed killers such as 2,4-D, should not be stored with other pesticides (primarily insecticides and fungicides) as they can volatilize and be absorbed by other pesticides.

Store pesticides in a cool place (40°-80°F), dry, well ventilated area that is not accessible to children and others who do not know or understand the safe and proper use of pesticides.

Any restricted pesticide or container contaminated by restricted pesticides must be stored in a secure, locked enclosure while unattended. That enclosure must bear a "pesticide storage" warning sign readable at a distance of 20'. If any pesticide has to be stored in other than its original container, that container must be labeled with the name and concentration of the active ingredient and the signal word and warning statements for the pesticide along with a copy

of the label. Keep an inventory of all pesticides stored in an area away from the storage site, so that it may be referred to in case of an emergency at the storage site.

Make available to personnel at all times: a respirator with chemical cartridge, gas mask with canister, goggles, rubber gloves and aprons, fire extinguisher and a detoxicant for spilled materials suggested by your local fire department. Instruct all personnel on proper use of the above equipment and on what to do in case of emergency. A shower stall with plenty of soap should be made available on the premises. Prompt washing in case of accidental spillage may be a matter of life and death.

Keep your local fire department informed of the location of all pesticide storage areas. Fighting a fire that includes smoke from burning pesticides can be extremely hazardous. Firefighters should be cautioned to avoid breathing any smoke from such a fire. A fire with smoke from burning pesticides may endanger people in the immediate area or community. They may have to be evacuated if the smoke from a pesticide fire drifts in their direction.

Winter Storage of Pesticides. Plan pesticide purchases so that supplies are used by the end of the growing season. When pesticides are stored for the winter, keep them at temperatures above freezing, under dry conditions and out of direct sunlight. The following points should be observed:

- Read the label. Special storage recommendations or restrictions will be printed on the label.
- Write the purchase or delivery date of the product on the label with waterproof ink. Products may lose their effectiveness over several years.
- Ventilation is important for storage of most pesticides.
- Store herbicides separately from other pesticides to avoid cross contamination. Below are signs of quality deterioration:

Formulation	General Signs of Deterioration
EC	Evidence of separation of components such as sludge or sediment. Milky appearance does not occur when water is added.
Oils	Milky appearance does not occur when water is added.
WP, SP	Excessive lumping; powder does not suspend in water.
D, G	Excessive lumping or caking

After freezing, place pesticides in warm storage (50°-80°F, or 10°-26.7°C). Shake or roll container every few hours to mix product or eliminate layering. If layering persists or if all crystals do not completely dissolve, do not use product. If in doubt, call the manufacturer.

Emergency Information

Human Exposure. If someone has swallowed or inhaled a pesticide or gotten it in the eye or on the skin:

- Call 911 if the person is unconscious, having trouble breathing, or having convulsions.
- Check the label for directions on how to give first aid.
- Call the Poison Control Center at 1-(800)-222-1222 for help with first aid information.

The National Pesticide Information Center (NPIC) 1-800-858-7378 (<http://npic.orst.edu/>) can also provide information about pesticide products and their toxicity.

Poisoning Information (Adapted from Ohio Vegetable Production Guide). Make sure your doctor has a copy of the **Note to Physicians** that is placed on the labels of dangerous pesticides.

Treatment for pesticide poisoning is very precise. The antidotes can vary for the different pesticides. In an emergency, call your doctor and provide specific information on the trade name and common name of the pesticide exposed to. Your doctor will then consult the center if necessary.

Tables 25, 26, and 27 list restricted fungicides, insecticides and herbicides that are commonly recommended for vegetable disease, insect, and weed control along with their oral and dermal LD₅₀ values. Materials with an LD₅₀ value of less than 100 should be considered highly toxic and handled with extreme caution.

Spills. The National Response Center can help you decide how to respond to a spill. They can be reached at: 1-(800)-424-8802. In addition, CHEMTREC maintains a large database of Material Safety Data Sheets, chemical information references, resources, and networks of chemical and hazardous material experts. CHEMTREC provides access to technical information regarding chemical products as well as telephone access to product specialists, chemists, or other experts. (1-800-262-8200 in the U.S. or 703-741-5500 outside the U.S.)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that all releases of hazardous substances (including radionuclides) exceeding reportable quantities be reported by the responsible party to the National Response Center (NRC). Title 40 of the Code of Federal Regulations Part 302 promulgates reportable quantities and reporting criteria. All the Extremely Hazardous Chemicals (EHS) that overlap with the CERCLA listed chemicals table (40 CFR Part 302.4) should be reported to NRC as well as to the LEPC and SERC.

For small pesticide spills or for more information, call the pesticide manufacturer or the National Pesticide Information Center (NPIC) at 1-800-858-7378.

Reporting a Spill: The National Response Center (NRC) is the sole federal point of contact for reporting oil and chemical spills. If you have a spill to report, contact NRC at 202-267-2675 or 1-800-424-8802 (toll-free) or visit <https://www.epa.gov/emergency-response/national-response-center> for additional information on reporting requirements and procedures. Producers should be aware that they may be required to report spills to their state Lead Agency (SLA) or their state Department of Environmental Protection.

Adjuvants

Adjuvants are non-pesticide chemicals that are added to pesticides or to pesticide spray mixtures to improve their chemical or physical characteristics. The most common types of adjuvants are nonionic surfactants, crop oil concentrates, spreader/stickers, drift control agents, buffering agents, compatibility agents, and foam-reducing agents. Adjuvants can reduce or eliminate many spray application problems by

performing specific functions. These functions include spreading, wetting, sticking, reducing drift, buffering, improving compatibility, reducing foaming, and improving the effectiveness of certain pesticides. Non-ionic surfactants are usually best for improving mixing of pesticides, for enhancing coverage of leaf surfaces, and for improving retention of the pesticide on the crop or weed. Although several adjuvants perform more than one function, no one adjuvant can perform all of these functions.

The most important source of information you have to determine whether or not to use an adjuvant is the pesticide label. Some prohibit the use of adjuvants due to the potential for severe crop injury or loss. Surfactants can increase the potential for crop injury by enhancing penetration of pesticides into the foliage or by causing burning on their own. High temperature and humidity enhance this potential injury. Avoid spraying in the mornings or middle of days when you can add the temperature (°F) and % humidity together and get 150 or more.

It is best to avoid silicone-based surfactants, ionic surfactants, or others that you are not familiar with unless you have a specific purpose for using them. If a label does not list a certain tank mix that you want to use AND, at the same time, does not preclude it, you may make the tank mix. Remember, however, that you should try it on a small scale first to make sure that there will be no problems.

Some labels provide no mention of adjuvants; in this case, consult the manufacturer or pesticide dealer.

Know Your Water

The pH of the water in your tank mix can sometimes affect the efficacy of pesticides. Insecticides, in particular, have a tendency to break down (hydrolyze) rapidly in alkaline water. Water pH can vary, depending on the source, from 5.0-9.5. Neutral water has a pH of 7.0, while alkaline water is higher than 7.0. If your water pH is much higher than 8.0, you may want to consider using an acidifying agent such as vinegar to lower the pH in the tank. Many of the pH-sensitive pesticides have acidifying agents in the formulation that moderate the effect of alkaline water. However, growers who suspect a pH problem should have their water tested. This can be done on the farm with pH test kits. Also, organic matter can tie up certain pesticides or clog nozzles, so be sure to use water that is free of organic debris.

Selection of sprayer tips

The selection of proper sprayer tips for use with various pesticides is very important. Nozzle tips must be selected according to the spray coverage, droplet size, and application volume desired. Flat fan-spray tips are designed for preemergence and postemergence application of herbicides. These nozzles produce a tapered-edge spray pattern that overlaps for uniform coverage when properly mounted on a boom. Standard flat fan-spray tips are designed to operate at low pressures (30-60 psi) to produce small- to medium-sized droplets that do not have excessive drift. Flood-type nozzle tips are generally used for complete fertilizer, liquid N, etc., and sometimes for spraying herbicides onto the soil surface prior to incorporation.

Full and hollow-cone nozzles deliver circular spray patterns and are used for application of insecticides or fungicides to

crops where thorough coverage of the leaf surfaces is extremely important and where spray drift will not result in crop injury of nearby plants. They are used when higher water volumes and spray pressures are recommended. With cone nozzles, the disk size and the number of holes in the whirl plate affect the output rate. Various combinations of disks and whirl plates can be used to achieve the desired spray coverage.

Calibration for Field Sprayers

(Adapted from the Rutgers Commercial Vegetable Production Guide, <https://njaes.rutgers.edu/pubs/commercial-veg-rec/pesticide-safety.pdf>). Calibration is the process of measuring and adjusting the amount of pesticide your equipment will apply over a target area. Periodic calibrations of sprayers, dusters, and granule distributors are necessary to ensure accurate delivery rates of pesticides per acre. Calibrations are made by measuring the total gallons of water applied per acre, in the case of sprayers, and the total pounds of dust or granules applied per acre, in the case of dust and granule distributors. Too little spray or dust applied results in inadequate distribution of toxicant over plant surfaces. Control is usually poor, and additional applications are required. Too much per acre is hazardous for the applicator, is frequently injurious to plants (phytotoxic), and could lead to excessive residues if applied close to harvest.

Width of Boom. The width of boom must be expressed in feet. The boom coverage is equal to the number of nozzles multiplied by the space between nozzles.

Ground Speed (mph). Careful control of ground speed is very important for accurate spray application. Select a gear and throttle setting to maintain constant speed. A speed of 2 to 3 miles per hour is desirable. From a "running start," mark off the beginning and ending of a 30 second run. The distance traveled in this 30 second period divided by 44 will equal the speed in miles per hour. Example: At a tractor speed of 1 mile per hour, you would travel 88' in 1 minute, 44' in 30 seconds or 500' in 5 minutes and 41 seconds.

Sprayer Discharge (gpm). Run the sprayer at a certain pressure, and catch the discharge from each nozzle for a known length of time. Collect all the discharge, measure the total volume and convert the volume to gallons. Divide this volume by the time in minutes to determine discharge in gallons per minute. Catching the discharge from each nozzle checks the performance of the individual nozzle which is a critical step in calibration. If there is more than 10% variation between any nozzles, all the tips should be replaced. When it is not convenient to catch the discharge from each nozzle, a trough may be used to catch the total discharge.

Before Calibrating. Review and complete the following checklist:

1. Thoroughly clean all nozzles, screens, etc., to ensure proper operation.
2. Check to be sure that all nozzles are the same, are made by one manufacturer, and have the same part number.
3. Check the spray patterns of all nozzles for uniformity. Check the volume of delivery by placing similar containers under each nozzle. All containers should fill at the same rate. Replace nozzles that do not have uniform patterns or do not fill containers at the same rate.

- Select an operating speed. Note the tachometer reading or mark the throttle setting. When spraying, be sure to use the same speed as used for calibrating.
- Select an operating pressure. Adjust pressure to desired psi according to the nozzle manufacture. Do this while pump is operating at normal speed and water is actually flowing through the nozzles. This pressure should be the same during calibration and field spraying.

Calibration Using the Jar Method. Any 1-quart or larger container, such as a jar or measuring cup, if calibrated in fluid ounces, can easily be used following the steps below. A specially designed calibration jar can be used; if you buy one, follow the manufacturer's instructions. Make accurate speed and pressure readings and jar measurements. Make several checks. Keep in mind that you are collecting less than a quart of liquid to measure an application rate of several gallons per acre for many acres.

- Measure a course on the same type of surface (sod, plowed, etc.) and same type of terrain (hilly, level, etc.) as that to be sprayed, according to nozzle spacing as follows:

Nozzle Spacing (in)	16	20	24	28	32	36	40
Course length (ft)	255	204	170	146	127	113	102

This area will be equal to 1/128 of an acre.

- Time the seconds it takes the sprayer to cover the measured distance at the desired speed. Average several runs. This is the time required to cover 1/128 acre.
- With the sprayer standing still, operate at selected pressure and pump speed. Catch the water from several nozzles for the number of seconds measured in step 2.
- Determine the average output per nozzle in ounces. The ounces per nozzle equal the gallons per acre applied by one nozzle per spacing.

Calibration for Boom or Airblast Sprayer. The following applies to any pesticide that is applied as a liquid spray.

- Fill sprayer with water.
- Spray a measured area (width of area covered x distance traveled) at constant speed and pressure selected from manufacturer's information.
- Measure amount of water necessary to refill tank (gallons used).
- Multiply gallons used by 43,560, and divide by the number of square feet in area sprayed. This gives gallons per acre.
- Add correct amount of spray material to tank to give the recommended rate per acre.

EXAMPLE:

Assume:
10 gal of water used to spray an area 660 ft long and 20 ft wide
Tank size - 100 gal / Spray material - 2 lb formulated product/A
Calculation:

$$\frac{\text{gal used} \times 43,560}{\text{area sprayed}} = \frac{10 \times 43,560}{660 \times 20} = 33 \text{ gal/A}$$

$$\frac{\text{tank capacity}}{\text{gal/A}} = \frac{100 (\text{tank size})}{33} = 3.03 \text{ acres sprayed per tank}$$

$$3.03 \times 2 (\text{lb/A}) = 6.06 \text{ lb material per tank}$$

Calibration for Granular Applications

The application equipment for granular fertilizer, herbicides, insecticides, etc. in many cases was not designed as precision equipment; therefore, extra care must be taken in calibration to get the results desired. Application rates of granular application equipment are affected by several factors: gate openings or settings, ground speed of the applicator, shape and size of granular material, and roughness of the ground. It takes a conscientious operator, effort, knowledge of equipment, and calibration to achieve accurate application rates. The first step to good application is to be sure the equipment is prepared for operation. Be sure all controls are free and work properly. Check and lubricate moving parts as necessary, remove corrosion, and tighten loose nuts and bolts.

Broadcast Applicators (Gravity-Drop or Spinner Applicators)

- From the label, determine the application rate.
- From the operators manual, set dial or feed gate to apply desired rate.
- On a level surface, fill hopper to a given level and mark this level.
- Measure test area - length of run will depend on size of equipment. It need not be one long run but can be multiple runs at shorter distances.
- Apply material to measured area, operating at the speed applicator will travel during application.
- Weigh amount of material required to refill hopper to the marked level.
- Determine application rate:

$$\text{Area covered (acres)} = \frac{\text{number of runs} \times \text{length of run (ft)} \times \text{width of application (ft)}}{43,560}$$

$$\text{Application rate (lb/A)} = \frac{\text{amount applied (pounds to refill hopper)}}{\text{area covered (acres)}}$$

NOTE: Width of application is width of the spreader for drop or gravity spreaders. For spinner applicators, it is the working width (distance between runs). Check operator's manual for recommendations, generally one-half to three fourths of overall width spread.

EXAMPLE:

Assume: 50 lb/A rate
Test run-200 ft
Four runs made
Application width-12 ft
11.5 lb to refill hopper

$$\text{Area covered} = \frac{4 \times 200 \times 12}{43,560} = 0.22A$$

$$\text{Application rate} = \frac{11.5}{0.22} = 52.27 \text{ lb/A}$$

- If application rate is not correct, adjust feed gate opening and recheck.

Calibration for Band Applicators

- From the label, determine application rate.
- From the operator's manual, determine applicator setting and adjust accordingly.
- Fill hopper half full.

4. Operate applicator until all units are feeding.
5. Stop applicator; remove feed tubes at hopper.
6. Attach paper or plastic bag over hopper openings.
7. Operate applicator over measured distance at the speed equipment will be operated.
8. Weigh and record amount delivered from each hopper. (Be sure all hoppers and all tubes deliver the same amount.)
9. Calculate application rate:

$$\text{Area covered in bands (acres)} = \frac{\text{number of bands} \times \text{length of run (ft)} \times \text{band width (ft)}}{43,560}$$

Application rate:

$$\text{Rate applied in bands (lb/A)} = \frac{\text{total amount collected (lb)}}{\text{area covered in bands (acres)}}$$

10. If not correct, readjust and recheck.

Calibration for Changing from Broadcast to Band Application.

Within a field, the treated area may be only a fraction of the total land area. Calculate application rates for portion of the field that is treated, using the ratio of band width to row spacing, as follows:

$$\frac{\text{Band width (inches)}}{\text{row spacing (inches)}} \times \text{broadcast rate per acre} = \text{amount needed per acre of field}$$

Calibration for Backpack Sprayers

Growers with diverse crops and small plantings often need to be able to apply pesticide to beds or plots of several hundred square feet. It is important to use the correct amount of pesticide in your backpack sprayer when spraying a small area, to mix and spray safely, and to follow the label instructions.

All measuring and mixing utensils used with pesticides or other chemicals should be clearly labeled with warnings that they are only to be used for measuring and mixing pesticides. Measuring equipment should be locked in the pesticide storage area. All equipment calibration should be done on the same surface to which the pesticide will be applied and at the same speed, pressure, etc.

Maintaining constant pressure can be difficult with sprayers that depend on continual hand pumping. To help with backpack sprayer calibration and application, constant flow nozzles are available. G.A.T.E. LLC manufactures a CF Valve that delivers a constant 14.9 psi recommended for spraying herbicides and a 21 psi for insecticides and fungicides. These are designed to deliver the same pressure and flow rate no matter what the pressure in the tank is above the designated pressure and shut off if the pressure in the tank falls below the designated pressure. SOLO makes a “pressure limiting valve” that actually has three settings of 5, 10 and 15 psi for their backpack sprayers that does the same thing.

Calibration will vary with the crop, crop stage, amount of canopy, and location of target pest in the crop. Seedlings will require far less material than a fully grown canopy. Match the amount of pesticide to the amount of water needed to spray the crop area at the target crop stage.

For products with rates listed in amount/acre:

1. Calculate what portion of an acre is being sprayed. Determine sq ft of area to be sprayed (multiply bed or

canopy width by row length by number of rows). Calculate what proportion of an acre this is (it may be a small fraction of an acre):

$$\text{Proportion of acre to be sprayed} = \frac{\text{number of sq. ft. to spray}}{43,560 \text{ sq. ft. per acre}}$$

2. Calculate how much pesticide to use. Multiply the label rate per acre for the crop and pest times the proportion of an acre to be sprayed.

$$\text{Amount of pesticide needed per acre} = \text{amount of acre to be sprayed}$$

3. Measure water needed per sq. ft. of crop. Add a known amount of water (eg 1 or 2 gallons) to the tank. Spray the water as if you were actually spraying your field. Remember, you must maintain constant pressure, constant walking speed, and consistent nozzle height and boom setup or wand motion to achieve the coverage you need. This amount will change with different crops and size of crop canopy. When the water is gone, stop and mark the spot. Measure the area you sprayed and calculate square feet (length of swath x width). Calculate how many gallons (or fluid ounces, for smaller areas) needed per sq ft.

$$\text{Gallon per sq. ft.} = \frac{\text{number of gallons used}}{\text{number of sq. ft. sprayed}}$$

This can also be calculated by timing how long it takes to spray a known area, then collecting the output for the same amount of time, at the same pressure. Divide the amount used by the area sprayed.

4. Determine total water needed:

$$\text{Gallons of water needed} = \text{gal per sq ft} \times \text{number of sq ft to be sprayed}$$

5. Mix the required amount of pesticide in required amount of water. Most commonly, it is best to add half the water, add the pesticide, agitate, then add the remaining water. Spray, using the walking speed, pressure, nozzle and boom setup or wand motion that you used for calibrating.

For products that give rates for backpack sprayers: Some pesticide label provide a rate of product to use per gallon, for backpack sprayers or smaller areas. If this is given, it is still important to calibrate to determine the amount of water used per unit area (sq. ft.). Add the labeled rate pesticide per gallon of water, adjusting the rate to match the fraction or number of gallons that will be used.

PROTECTING GROUNDWATER AND SURFACE WATERS

There is considerable public concern about water quality, and agriculture is coming under increasing scrutiny regarding practices that can affect water quality. Many pesticides and fertilizers are soluble in water and can leach through the soil to contaminate underlying groundwater or run off to contaminate surface waters. Several factors affect the movement of chemicals in or with the soil and their likelihood of reaching groundwater or surface water. Consideration of these factors can minimize the threat to water.

Solubility is the ability of a chemical to dissolve in a solvent. Pesticides that are highly soluble in water are often desirable from an applicator's perspective because they are less likely to clump and/or separate. However, they also pose potential water quality issues as they can easily leach into the groundwater supply. If practical, to reduce leaching potential select the least soluble material and use the lowest effective rate.

Adsorption is the binding of a chemical to the surfaces of soil particles and organic matter. Some chemicals are tightly adsorbed and do not easily leach from soils; however, they have a higher risk of moving with soil when there is surface erosion. Others have low adsorption, and will leach more easily.

Persistence refers to the amount of time a chemical will stay in the environment before being broken down into nontoxic substances. The rate of breakdown is affected by sunlight, temperature, soil pH, moisture and microbial activity. Pesticide persistence is measured in terms of half-life, which is the length of time needed for one-half of the amount applied to break down. Persistent chemicals break down slowly, increasing the chance for them to leach into the soil. Conversely, short-lived materials may be degraded before significant leaching occurs. Many pesticides are broken down by sunlight (photodegradation) and/or microbial action. Incorporation of pesticides into the soil reduces or eliminates photodegradation. As depth in the soil increases, there is less microbial degradation. Any practice that slows degradation increases persistence and the likelihood of leaching. Generally, foliar applied materials are more likely to break down before significant leaching occurs than those that are applied to the soil.

Soil Characteristics and Topography: Soil texture and organic matter greatly influence the movement of pesticides and fertilizers. Fine textured soils and those with high amounts of organic matter are highly adsorptive, whereas sandy soils low in organic matter are not. Highly permeable soils with permeable underlying layers allow for rapid downward movement of water and dissolved chemicals. Steep grades and long slopes allow water to build up speed and carry soil and contaminants off-site. Know your soils and apply chemicals accordingly.

Water Table: High water tables are especially vulnerable to contamination because little time is required for chemicals to reach groundwater. Tile drainage allows contaminants to leave the field faster and enter surface waters directly through outlet pipes. Excessive precipitation or irrigation, or poorly timed irrigation, immediately after pesticide or fertilizer applications, can also move contaminants off-site and into surface and ground water quickly.

Leachable pesticides: The following are some pesticides used on vegetables that have been identified as having high leaching potential:

alachlor (Lasso)	DCPA (Dacthal)	metribuzin (Sencor/Lexone)
atrazine (Aatrex)	methomyl (Lannate)	simazine (Princep)
bentazon (Basagran)	metolachlor (Dual)	
chlorothalonil (Bravo)	cyanazine (Bladex)	

Fertilizer characteristics: Nitrogen (N) in the nitrate form is highly soluble, persistent and not adsorbed to soil particles. Nitrate N is not only leachable but is recognized as a health threat at concentrations above 10 ppm in drinking water.

Infants and the elderly are most susceptible to nitrate in drinking water. The ammonium form of N is adsorbed by soil particles and is less subject to leaching. However, ammonium N is converted to nitrate N in the soil, and this can occur quite rapidly. Note that sources of N, including organic materials and urea, are converted in the soil to ammonium and then to nitrate.

Appropriate management practices can reduce the likelihood of nitrate leaching. Anytime large amounts of N are applied, significant leaching can occur if there is heavy rain. By applying some of the needed N at planting and the rest during one or more sidedressings, you can avoid having large amounts of nitrate present at any one time. Not only can this reduce leaching, it can improve production by providing N during periods of greatest crop uptake.

Nitrogen left over in the soil at the end of the season is highly subject to leaching. A cover crop should be planted to take up unused N. The N will again become available for future crops as the cover crop breaks down.

Phosphorus (P) is tightly bound by the soil, but if over-applied, can leave the field through soil erosion or leaching and concentrate in and contaminate surface waters. Excess application and accumulation of P in the soil can be associated with high application rates of mineral fertilizers, manure, manure-based compost, sludge or livestock grazing. Monitor P levels by conducting soil tests on a regular basis and avoiding excess applications.

Contact Cooperative Extension and the Natural Resource Conservation Service about questions you may have regarding the use of certain fertilizers and pesticides on your soils.

BIORATIONAL AND ORGANIC PESTICIDES

Pesticides vary in their toxicity to people and to non-target organisms, and in their potential ecological impact. Pest control materials that are relatively non-toxic to people with few environmental side-effects are called "biorational" pesticides in this Guide. Biorational pesticides mostly include the following categories further defined in this section: biopesticide, organic pesticide, minimum-risk pesticide, and biological control. Federal law governs pesticide registration through the EPA, and materials derived from living things are defined as "biopesticides". Organic production is regulated through the USDA National Organic Program which defines what inputs are allowed for pest management. "Organic" and "biopesticide" are partially overlapping categories, and each is defined by specific criteria that are unique. "Minimum risk pesticide" is another category that is defined by EPA; these are exempt from federal registration. "Biological control" describes living organisms that suppress pests. Some biological controls are naturally occurring, some are insects purchased by farmers for pest control, and some are microbes formulated for sale as biopesticides.

All tables in this section include products that are registered as pesticides as well as some that are exempt from EPA registration. None are federally restricted-use products. Most have low dermal and oral LD₅₀ values and they carry the minimum EPA signal word of "Caution". However, some organic pesticides such as copper sulfate have a high dermal and oral LD₅₀ value and carry the EPA signal word "Danger" on their label.

Types of Biorational Pesticides

Botanicals are plant-derived materials such as pyrethrin, azadiractin, and extracts of plants such as *Chenopodium ambrosioides* and *Swinglea glutinosa*. Plant-derived oils such as neem oil, canola oil, and sesame oil are also included in this group. Botanicals are generally short-lived in the environment, as they are broken down rapidly in the presence of light and air. Products generally have low mammalian toxicity and a broad spectrum of activity. Many botanicals are considered minimum risk pesticides and are exempt from registration by EPA (see below).

Microbial pesticides are formulated from living microorganisms and/or their by-products. Microbial insecticides tend to be selective, so specific pests may be controlled with little or no effect on non-target organisms, while most microbial disease control products have a wider spectrum of activity. Microbial insecticides may be derived from bacteria (e.g. *Bacillus thuringiensis*, spinetoram and spinosad, *Chromobacterium subtsugae*), virus (e.g. nuclear polyhedrosis virus of corn earworm) or fungi (e.g. *Beauveria bassiana*). Microbial disease control products are living organisms, including beneficial fungi and bacteria. Examples of microbial disease control organisms are the fungus *Trichoderma harzianum* and the bacterium *Bacillus subtilis*. While these active ingredients are generally approved for organic production (OMRI listed) because of their natural origin, certain formulated products are prohibited because the inert ingredients or procedures used in making the product are prohibited.

Minerals. Some pesticides made from minerals, mined from the earth and minimally processed, are allowed in organic production. Kaolin clay, copper hydroxide, and iron phosphate are examples (see Table 21, page 76 and Table 23, page 79).

Synthetics. Minerals and other natural materials that are heated, chemically reacted, or mixed with surfactants may be considered synthetics. Synthetics also include insect growth regulators (IGR), which interrupt or inhibit the life cycle of a pest. They may also work by strengthening plant defenses. National organic standards include some allowed synthetics.

Biopesticides

Biopesticides, as defined by EPA, are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. As of April 2016, there are 299 registered biopesticide active ingredients and 1401 active biopesticide product registrations. EPA generally requires less data to register a biopesticide than to register a conventional pesticide, thus the registration process is faster. Categories of biopesticides include:

- Microbial pesticides, in which a microorganism (e.g., a bacterium, fungus, virus or protozoan) is the active ingredient
- Plant-Incorporated-Protectants (PIPs), in which pesticidal substances are produced by crop plants as a result of genetic material being added to the plant (e.g., *Bt* insecticidal protein)
- Biochemical pesticides, which are naturally occurring substances that control pests by non-toxic mechanisms, such as sex pheromones that interfere with mating and scented plant extracts that attract insect pests to traps. With plant-incorporated protectants, the toxin and its genetic material, but not the plant itself, are regulated by EPA.

Biopesticides generally fit well into an integrated pest management (IPM) strategy, which relies on monitoring for early detection of pests and emphasizes the use of selective products that protect crops while minimizing negative effects on water, air and soil, and on pollinators and beneficial insects. The purpose of this section is to bring these types of products together to help growers make decisions about pesticides and biological controls to use on their farm.

Pesticides in Organic Production

The USDA National Organic Program allows application of biological, botanical, or mineral inputs, when cultural practices are insufficient to prevent or control crop pests, weeds, and diseases. Most of these are non-synthetic and/or minimally-processed.

NOTE: not all biopesticides are labeled for use in certified organic agriculture. The grower is responsible for determining whether materials are allowed under organic standards. Sometimes this may be a challenge because some materials labeled as organic by the manufacturer may not actually be allowed by the USDA National Organic Program. The Organic Materials Review Institute (OMRI) is recognized by the National Organic Program as an organic material review organization. It lists products it finds suitable for certified organic production. These products are generally allowed without restriction, but some are regulated and subject to restrictions. In some cases, OMRI notes that certain formulations of a product are permitted and others are not. The list of substances approved by OMRI is subject to change.

Be sure to check with your certifier in advance to be certain that the materials and practices you plan to use are approved by your certifier, and that you understand any restrictions on use. For the most up-to-date OMRI list, visit the OMRI web site at: www.omri.org. When mentioned in tables or in crop chapters, this Guide designates approved organic materials with a superscript OG^(OG), which means they were “OMRI listed” at the time of publication (June, 2019).

Minimum risk (exempt) pesticides

These are a special class of pesticides that are not subject to federal registration requirements because their ingredients, both active and inert, are demonstrably safe for the intended use. This exemption falls under section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Of the New England states, ME, NH, RI and VT require state registrations for these products while MA and CT allow exemption for all products that meet the minimum risk criteria and are on the federal 25(b) list. For more information, please contact your state’s pesticide registration office (see Pesticide Safety and Use, page 67). The list of 25(b) exempt materials includes the following: corn gluten meal; sodium chloride; corn, linseed, sesame, soybean, and cottonseed oil; garlic and garlic oil; and essential oils including rosemary, mint, thyme, geranium, lemongrass, cinnamon and rosemary. Some pest control products listed in this guide meet the criteria for exemption and do not have EPA pesticide registration or a pesticide label. More on this class of pesticides can be found at: <https://www.epa.gov/sites/production/files/2018-01/documents/minrisk-active-ingredients-tolerances-jan-2018.pdf>.

Table 21: Biorational and Selective Insecticides and Miticides

Active Ingredients	Trade Name	Target Pests	Comments
azadirachtin	Amazin Plus 1.2%ME ⁰⁶ ; Aza-Direct ⁰⁶ ; AzaGuard ⁰⁶ ; Azatin 0 ⁰⁶ ; XL; Azatrol EC ⁰⁶ ; Azerg ⁰⁶ (M); Ecozin Plus 1.2%ME ⁰⁶ ; Molt-X ⁰⁶ ; Neermix 4.5 ⁰⁶ ; Ormazin 3%EC	Aphids, caterpillars, leafhoppers, leafminers, thrips, whiteflies, beetles, and other insects	An insect growth regulator extracted from the seeds of the neem tree. Works by contact or ingestion against immature stages, and has antifeedant properties.
<i>Bacillus thuringiensis</i> subsp. <i>aizawai</i>	Xentari ⁰⁶	Caterpillars, as listed for <i>Bt kurstaki</i> , as well as cross-striped cabbageworm, armyworms, cutworm	Use in rotation with <i>Bt kurstaki</i> products to prevent resistance. May be used in greenhouse or field.
<i>Bacillus thuringiensis</i> subsp. <i>israelensis</i>	Gnatrol WDG ⁰⁶	Fungus gnats	For use in greenhouse.
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i>	CoStar ⁰⁶ ; Deliver ⁰⁶ ; Dipel ES, Dipel DF ⁰⁶ ; Javelin WG ⁰⁶	Many caterpillars, including cabbage looper, diamondback moth, imported cabbageworm, European corn borer, hornworm	Must be ingested. Apply when caterpillars are actively feeding. Safe on beneficial insects. For some species, more effective on smaller larvae.
<i>Bacillus thuringiensis</i> subsp. <i>tenebrionis</i> strain SA-10	Trident ⁰⁶	Colorado potato beetle	For use on potato, tomato, and eggplant. Must be ingested. (Trident currently unavailable due to formulation and shipping issues)
buprofezin	Talus 70DF	Leafhoppers, mealybugs, planthoppers, whiteflies	Insect growth regulator.
<i>Burkholderia</i> spp. (heat-killed) Strain A396 and spent fermentation media	Venerate XC ⁰⁶ ; Majestene ⁰⁶	Caterpillars, cutworms, aphids, mites, thrips, whiteflies	Works by contact and ingestion to disrupt insect exoskeletons and interfere with molting.
capsicum oleoresin extract, garlic oil, soybean oil	Captiva	Caterpillars, mites, thrips, leafhoppers, whiteflies	Has anti-feedant, anti-egg laying, and irritant activity, and weakens cuticles of immature stages of insect and mite pests.
<i>Chenopodium ambrosioides</i> extract	Requiem	Aphids, whiteflies, thrips, leafminer, mites	Contact insecticide/acaricide. Can be applied for ovicidal control. Start when populations are at threshold. Compatible with beneficial insects.
chlorantraniliprole	Coragen	Caterpillars, Colorado potato beetle, leafminers	May be used as soil or transplant water treatment at planting, in drip or as foliar. Avoid run-off in surface waters. Non-toxic to bees.
<i>Chromobacterium subsugae</i> strain PRAA4-1	Grandevo ⁰⁶	Caterpillars, aphids, whiteflies, mites, leafhoppers, thrips	A selective biological insecticide/miticide containing fermentation solids. Works as a stomach poison upon ingestion. No systemic activity. Toxic to bees exposed to direct treatment or residues on blooming crops or weeds.
clarified hydrophobic extract of neem oil	Triact 70 ⁰⁶ , TriIt ⁰⁶ , Y ⁰⁶	Primarily labeled for (but not limited to) mite control	Can be used to control mites. For best results use when population levels are low to prevent build-up. Repeat applications are needed.
clove oil, thyme oil and cinnamon oil	Ecotrol G2 ⁰⁶	Root maggots, wireworm, cutworm, Symphylans	Soil-incorporated volatile plant oils on a corn cob carrier, applied before, during or after planting. Exempt from registration and reporting under Federal EPA standards.
cryolite	Prokil Cryolite 96	Colorado potato beetle (larvae only), cucumber beetle, flea beetle, cutworms, some caterpillars	Stomach poison, must be ingested. Sodium aluminum fluoride mineral, applied as spray or dust. Reapply to cover new growth. May cause extensive wear of nozzles.
cyromazine	Trigard	Leafminer, Colorado potato beetle	An insect growth regulator.
diflubenzuron	Dimilin	Armyworms, pepper weevils	A selective insect growth regulator that disrupts the molting process of insect larvae.
etoxazole	Zeal	Mites	A mite growth regulator that works as an ovicide and larvicide.
flonicamid	Beleaf	Aphids, plant bugs, whiteflies	A pyridinecarboxamide that works by contact and ingestion. Feeding stops rapidly and mortality will follow.
flubendiamide (Note: All flubendiamide registrations were canceled by the EPA in 2016. Growers may use up existing stock.)	Belt SC	Caterpillars including armyworms, loopers, hornworm, corn earworm, European corn borer	A diamide, active by insect larval ingestion, leading to a rapid cessation of feeding followed by death. Labeled for use as a foliar spray on Brassicas and turnip greens, leafy vegetables, sweet corn, cucurbits, fruiting vegetables, and legumes to control caterpillars.

This table includes products that are registered as pesticides as well as some that are exempt from EPA registration. Most have low toxicity to bees and beneficial insects. None are federally restricted-use products. Most have dermal and oral LD₅₀ values over 2,000 mg/kg (see Table 25 and 26 for LD₅₀ values for insecticides and fungicides). **Selective insecticides** have efficacy on specific insect groups, or a specific life stage, and are therefore safe for non-target beneficial insects.

Table 21: Biorational and Selective Insecticides and Miticides (continued)

This table includes products that are registered as pesticides as well as some that are exempt from EPA registration. Most have low toxicity to bees and beneficial insects. None are federally restricted-use products. Most have dermal and oral LD₅₀ values over 2,000 mg/kg (see Table 25 and 26 for LD₅₀ values for insecticides and fungicides). **Selective insecticides** have efficacy on specific insect groups, or a specific life stage, and are therefore safe for non-target beneficial insects.

Active Ingredients	Trade Name	Target Pests	Comments
flupyradifurone	Sivanto	Aphids, leafhoppers, whiteflies, Colorado potato beetles, squash bugs	A broad-spectrum insecticide in a new class of chemistries, the Butenolides. Acropetally systemic, and translaminar. No toxicity to bees in lab tests.
insecticidal soap (Potassium salts of fatty acids)	Des-X ⁰⁶ , M-Pede ⁰⁶	Aphids, leafminers, mites, thrips, whiteflies	Works on contact. Can be phytotoxic to some crops, test on small plot. Avoid treatment when plants are stressed. May also harm some beneficials. Also active against powdery mildews.
iron phosphate	Sluggo: Snail and Slug Bait ⁰⁶	Snails, slugs	Bait which causes feeding to cease. Death occurs over 3-5 days. Exempt from tolerance and has a zero hour re-entry interval due to low toxicity to people and wildlife.
kaolin	Surround WP ⁰⁶	Flea beetle, striped cucumber beetle, leafhopper, thrips	Interferes with insects' ability to recognize their host; particles cling to cuticle. Plant leaves turn white but growth is not inhibited. Reapply after heavy rain. To avoid lumps in mixing, form a slurry, then dilute. Maintain agitation.
metalddehyde	Deadline Bullets	Slugs, snails	A toxic bait. Not for direct application to or contamination of edible portions of the plant; to be applied as a band treatment between rows after formation of edible parts. Long-lasting; resistant to rain and watering.
methoxyfenozide	Intrepid	Many species of caterpillars	Mimics molting hormone; causes premature molt and death.
novaluron	Rimon	Caterpillars, beetles, leafminers, squash bugs, thrips, whiteflies	An insect growth regulator for use on immature stages.
petroleum oil (mineral, paraffinic oils)	JMS Stylet Oil, Organic JMS Stylet Oil ⁰⁶ , Suffoil X ⁰⁶	aphids, leafminers, beetle larvae, mites, thrips, leafhoppers, whiteflies	A horticultural oil (80% petroleum oil) insecticide, miticide and fungicide. Kills eggs, larvae and nymphs of insects and mites and adults of soft-bodied insects through suffocation. Registered for use as a foliar spray on a variety of crops. Also labeled for certain diseases.
pymetrozine	Fulfill	Aphids	Works by contact and ingestion, translaminar with long residual.
pyrethrin	PyGanic EC5.0I ⁰⁶ , PyGanic EC1.4 ⁰⁶	Asparagus beetle, blister beetle, cucumber beetle, flea beetles, Mexican bean beetle, potato leafhopper, many caterpillars, aphids, stink bugs	Botanical insecticide with broad-spectrum activity. Contact toxin with rapid knockdown but short period of activity (non-persistent). Highly toxic to fish. Derived from a chrysanthemum species cultivated in Africa. Some formulations are approved for organic crops.
pyriproxyfen	Esteem, Distance IGR, Knack	Thrips, whiteflies shoreflies, fungus gnats	Label may include greenhouse or field use. An insect growth regulator that suppresses development of embryo within the egg, immature, and pupal stages of the insect. No activity against adult insects.
rosemary oil, peppermint oil, other essential plant oils	Ecotrol Plus ⁰⁶	Aphids, beetles, bugs, early stages of caterpillars, leafminers, mites, thrips	Works on contact as an insecticide and miticide. Greenhouse and field use. Thorough coverage is needed. Exempt from registration under Federal EPA standards.
soybean oil	Golden Pest Spray Oil ⁰⁶ , Captiva	Primarily soft-bodied insects	A soybean-derived horticultural oil that works as a contact insecticide, as well as a feeding and oviposition deterrent. Exempt from registration under Federal EPA standards.
spinetoram	Radiant	See spinosad, below.	A second-generation spinosyn, similar to spinosad, below.
spinosad	Blackhawk, Entrust ⁰⁶ , Seduce Insect Bat ⁰⁶ , GF-120 Naturalyte ⁰⁶	Caterpillars, Colorado potato beetle, asparagus beetle, flea beetle, leafminers, thrips. Baits labeled for cutworms, earwigs (Seduce) or fruit flies (GF-120)	Acts both as a contact and stomach toxin. Derived from soil bacterium <i>Saccharopolyspora spinosa</i> . Non-disruptive to most predator insect species and some parasitoids. Rotate with other selective biorationals to prevent resistance.
spiromesifen	Oberon	Whiteflies, nymphs & pupae, mites	Contact insecticide and miticide.
sulfur	Microthiol Dispers ⁰⁶	Mites	Micronized wettable sulfur, also labeled as a fungicide.
tebufenozide	Confirmer	Caterpillars	Selective insect growth regulator.

The symbol ⁰⁶ indicates a pesticide that has been listed by the Organic Materials Review Institute (OMRI) as compliant with the National Organic Standards and therefore approved for use in organic production.

Table 22: Biological Controls for Insect Pests

The products and living organisms listed in this table suppress pests on vegetable farms. Some biological controls are naturally occurring, some are insects purchased by farmers for pest control, and some are microbes formulated for sale as biopesticides. Most are exempt from EPA registration, and all are allowable for organic production.

Part 1. Established beneficial insects that live on New England farms

Scientific name	Common Name	Target Pests	Comments
<i>Chrysopa</i> and <i>Chrysoperla</i> spp.	Green lacewings	Aphids, thrips, mites, whiteflies, leafhoppers, small caterpillars, insect eggs	Larvae feed voraciously on many small insect pests. Common throughout the US, and available commercially.
<i>Coleomegilla maculata</i>	Twelve-spotted ladybeetle	Aphids, small caterpillars, small beetle larvae, insect eggs	Native to North America. Both adults and larvae are predators. Wide range of prey and of crops and habitats. Feeds on newly hatched larvae as well as insect eggs. Also eats pollen.
<i>Cotesia congregatus</i>	Braconid wasp	Tomato hornworm	Parasitic wasp that lays eggs in hornworm caterpillars.
<i>Cotesia rubecula</i>	Braconid wasp	Imported cabbageworm (ICW)	Parasitic wasp that lays eggs in small ICW. Exits and spins oval, white cocoon. Introduced to New England in 1988; now well established.
<i>Harmonia axyridis</i>	Multicolored Asian ladybeetle	Aphids	Adults have many variable markings. Both adults and larvae are predators. Renowned for invading homes in fall. May be a pest of grapes. Introduced to North America; widespread range.
<i>Orius insidiosus</i>	Insidious flower bug	Aphids	Commonly found in corn. Small (3 mm).
<i>Podisus maculiventris</i>	Spined soldier bug	Beetle larvae, caterpillars, insect eggs, aphids	Prey includes Colorado potato beetle. Both adults and nymphs are predators. Uses piercing sucking mouthparts to feed on soft-bodied insects.
Syrphid species	Syrphid fly larva (immature of hover fly)	Aphids, small caterpillars	Adult hover flies (Syrphids) mimic bees and feed in flowers. Immatures are voracious aphid predators; legless, cream or brown in color, found in aphid colonies.

Part 2: Biological control organisms, released or applied to crops

<i>Beauveria bassiana</i> Strain GHA	Mycotrol ESO, Botanigard	Aphids, whiteflies, thrips, Colorado potato beetle	This fungus penetrates the insect cuticle, fills its body, kills it, and releases more spores. Apply in the evening and target coverage of lower leaves, as spores are inactivated by sunlight. Use preventatively based on monitoring, before pests reach high levels. Can be tank mixed with other microbials for Colorado potato beetle.
<i>Isaria fumosorosea</i> Apopka Strain 97 (formerly <i>Paecilomyces fumosoroseus</i>)	PFR-97 ⁰⁶ , Preferal ⁰⁶	aphids, mites, thrips, whiteflies, leafminers, rootworms, wireworms, grubs, caterpillars	A naturally-occurring fungus that penetrates the cuticle of insect pests.
<i>Metarhizium anisopliae</i> Strain F52	Met 52EC	thrips, whiteflies, mites	Composed of spores of a naturally occurring insect pathogenic fungus. Spores attach to the insect and hyphae penetrate the exoskeleton, growing inside and causing death in 3 to 7 days. Labeled for use as a foliar spray or soil drench on field and greenhouse onions to control thrips, and on field and greenhouse celery, lettuce, spinach, peppers, and tomatoes to control thrips, whiteflies, and mites. Persistence will generally be higher when incorporated into soil, but may be effective for a few months even in foliar applications.
<i>Pediobius faveolatus</i>	No common name	Mexican bean beetle	Small parasitic wasp of the <i>Eulophid</i> family, which attacks larvae of the Mexican bean beetle. Releases should be timed to coincide with egg hatch because wasps lay eggs in young larvae, which are then killed and form a pupal case, or 'mummy' from which a new adult wasp will emerge.
<i>Steinernema</i> and <i>Heterorhabditis</i> species	Beneficial nematodes	Cutworms, white grubs, wireworms, maggots, beetle larvae, soil-dwelling adult insects	Nematodes are very small roundworms. Some species are plant pathogens, but some attack soil-dwelling insects and two in particular (<i>Steinernema</i> and <i>Heterorhabditis</i>) have been mass-reared for commercial use. These seek out and penetrate their host insects, multiply within the host and kill it. They are most likely to be effective against the soil-dwelling immature stages of susceptible hosts. Nematodes require moist soil conditions to survive.
<i>Trichogramma ostrinia</i>	No common name	European corn borer	Tiny parasitic wasp that oviposits in the eggs of European corn borer. Its larvae grow and pupate in the eggs, preventing borer hatch. Start release when ECB flight begins. In sweet corn, release at 30 to 60k per acre per week, for 2 to 3 weeks per block. In pepper, release 90 to 120k per acre per week over 4 weeks. Reproduces in season but does not overwinter. Available from IPM Laboratories, Locke, NY.
<i>Trichogramma pretiosum</i>	No common name	Caterpillar eggs	May be used in Brassica crops and other crops with caterpillar pests.

Table 23: Biorational and Organic Disease Control Materials			
The products in this table are botanical, mineral, and synthetic biorational pesticides labeled for disease control in vegetable crops. The symbol OG indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production.			
Active Ingredient and Trade Name	Target Pests	Labeled Crops	Comments/Material Type
Acibenzolar-S-methyl (Actigard 50 WG)	Downy mildews, bacterial diseases, rusts	Crucifers, tomato, spinach	Synthetic, Plant defense activator.
Copper sulfate (Basic Copper 53 ^{OG})	many bacterial and fungal diseases	Most crops	Mineral
Copper hydroxide (Champ WG ^{OG})	Bacterial blight, black rot (<i>Xanthomonas</i>), downy mildew, powdery mildew, Anthracnose, <i>Phomopsis</i> , late blight, <i>Botrytis</i> , leaf spots	Most crops	Mineral
Cottonseed Oil, Corn Oil, Garlic Oil (Mildew Cure ^{OG})	Powdery mildew	Most crops	Botanical
Cuprous oxide (Nordox 75 WG ^{OG})	Bacterial blight, black rot (<i>Xanthomonas</i>), downy mildew, powdery mildew, Anthracnose, <i>Phomopsis</i> , late blight, <i>Botrytis</i> , leaf spots	Most crops	Mineral
Hydrogen dioxide (OxiDate 2.0 ^{OG})	<i>Alternaria</i> , <i>Phytophthora</i> , <i>Pythium</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> Wilt, <i>Sclerotinia</i> , Anthracnose, bacterial blight, <i>Botrytis</i> , powdery mildew, rust	Beans, cucurbits, celery, crucifers, leafy vegetables tomato, pepper, onions, potato, herbs, root crops	Synthetic. Contact activity only
Kaolin (Surround WP ^{OG})	Powdery mildew, sunburn and heat stress.	All crops	Mineral.
Neem Oil (Trilogy ^{OG} , Triact 70 ^{OG})	Anthracnose, <i>Botrytis</i> , downy mildew, powdery mildew, scabs, rusts, leaf spots and blights	Most crops	Botanical
Oils, Petroleum based (JMS Stylet-Oil ^{OG} , Civitas ^{OG} , & Suffoil-X ^{OG})	<i>Alternaria</i> , Gummy Stem blight, Powdery mildew, Rust	Most crops	Synthetic and natural oils
Potassium Bicarbonate (Kaligreen ^{OG} , MilStop ^{OG})	<i>Alternaria</i> , Anthracnose, <i>Botrytis</i> , downy mildew, Fusarium, Leaf spots, <i>Phytophthora</i> , powdery mildew	Beans, crucifers, cucurbits, eggplant, lettuce, peppers, potato, tomato, spinach, wheat	synthetic, Biopesticide, Armicarb 100 is not OMRI listed, but MilStop and Kaligreen are.
Potassium Phosphite (Helena ProPhyt)	Downy mildews, <i>Phytophthora</i> species, <i>Pythium</i> species	Cucurbits, crucifers, onion, potato, tomato, lettuce, spinach	synthetic, Systemic. Drench at transplant.
Mono- and dibasic sodium, potassium, and ammonium phosphites (Phostrol)	Downy mildews, <i>Phytophthora</i> species, <i>Pythium</i> species	Most crops	synthetic, Use caution when using in a tank mix
Monopotassium phosphate (Nutrol)	Powdery Mildew	Cucurbits, peppers, and tomatoes	Synthetic, Can be used in greenhouse on some crops
Potassium silicate (Sil-MATRIX)	Powdery Mildew, Leaf spots	Most crops	Mineral, Broad spectrum preventive fungicide
Reynoutria sachaliensis Extract (Regalia ^{OG})	Powdery Mildew, <i>Botrytis</i> , Leaf spots, Bacterial spot, speck, and canker	Cucurbits, peppers, lettuce, tomato, strawberry, grapes	Botanical, Plant defense activator. Use caution in tank mix. OMRI listed.
Rosemary and Clove Oils (Phyta-Guard EC)	Powdery Mildews, bacterial spot	Most crops	Botanical
Rosemary, Clove, and Thyme Oils (Sporan EC)	Bacterial Spot, Early Blight, Gray Mold, Late Blight, Powdery mildew, Downy mildew	Most crops	Botanical
Rosemary, Thyme, and Clove Oil (Sporatec ^{OG})	Anthracnose, <i>Botrytis</i> , downy mildew, powdery mildew, leaf spots, rusts, bacterial spot	Most crops	Botanical
Streptomycin Sulfate (Agri-Mycin 17)	Bacterial diseases	Celery, peppers, tomato, potato	Biological anti-biotic
Sesame Oil (Organocide ^{OG})	Powdery Mildew, Leaf spots	Most crops	Botanical
Sulfur (Micro Sulf ^{OG} , Microthiol Disperss ^{OG} , Kumulus DF ^{OG})	Powdery mildew, leaf spots	Most crops	Mineral

Table 24: Microbial Disease Control Products				
The materials listed in this table are formulated from living microorganisms and/or their byproducts. The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production.				
Trade name	Active ingredient	Target Diseases	Labeled crops	Comments
Actinovate AG ^{OG}	<i>Streptomyces lydicus</i>	Downy mildew, powdery mildew, <i>Botrytis</i> , <i>Sclerotinia</i> spp., <i>Pythium</i> , <i>Phytophthora</i> , <i>Fusarium</i> , <i>Rhizoctonia</i>	Greenhouse use only for vegetable crops	Seed and soil treatment (drench/in-furrow), greenhouse foliar sprays
Bio-Save 10 LP ^{OG}	<i>Pseudomonas syringae</i> Strain ESC-10	<i>Fusarium</i> and <i>Helminthosporium</i> storage rots	Potato	Postharvest application
Bio-Tam ^{OG}	<i>Trichoderma asperellum</i> & <i>Trichoderma gamsii</i>	<i>Fusarium</i> , <i>Rhizoctonia</i> , <i>Pythium</i> , <i>Phytophthora</i> , <i>Sclerotinia</i> , <i>Sclerotium</i> , <i>Verticillium</i>	Corn, cole crops, fruiting vegetables, cucurbits, leafy vegetables, legumes, root, tuber, and corm vegetables, herbs, onions	Soil treatment
Companion Liquid (& WP) Biological Fungicide ^{OG}	<i>Bacillus subtilis</i> GB03	Anthrachnose, <i>Botrytis</i> , bacterial diseases, Powdery mildew, <i>Phytophthora</i> , <i>Pythium</i> , <i>Rhizoctonia</i> , Leaf spots	All crops	Soil treatment, hydroponics, seed treatment
Cease ^{OG}	<i>Bacillus subtilis</i> QST 713 strain	<i>Rhizoctonia</i> , <i>Pythium</i> , <i>Phytophthora</i> , <i>Fusarium</i>	Most crops	Soil drench, OMRI listed, greenhouse use
Contans WG ^{OG}	<i>Coniothyrium minitans</i> Strain CON/M/91-08	<i>Sclerotinia sclerotiorum</i> , <i>Sclerotinia minor</i>	Most crops (Bayer formula NOT labeled for tomato)	Soil treatment
DiTera DF ^{OG}	<i>Myrothecium verrucaria</i> Strain AARC-0255	Nematodes	Celery, lettuce, spinach, crucifers	
Double Nickel ^{OG}	<i>Bacillus amyloliquefaciens</i>	<i>Botrytis</i> , <i>Alternaria</i> , fungal leaf spots & blights, powdery mildew, downy mildew, soilborne pathogens: <i>Rhizoctonia</i> , <i>Pythium</i> , <i>Fusarium</i> , <i>Sclerotinia</i> , (suppression only: rust, late blight, early blight),	Cucurbits, fruiting and leafy vegetables, brassicas, asparagus, bulbs, legumes/beans, sweet corn & popcorn, herbs	
Mycostop ^{OG}	<i>Streptomyces griseoviridis</i> Strain K61	<i>Fusarium</i> , <i>Alternaria</i> , <i>Phomopsis</i> , <i>Botrytis</i> , <i>Pythium</i> , <i>Phytophthora</i> , <i>Rhizoctonia</i>	Beans, lettuce, carrots, crucifers, onions, spinach, tomato, root crops, herbs	Seed or soil treatment
Obtego ^{OG}	<i>Trichoderma asperellum</i> ICC 012 <i>Trichoderma gamsii</i> ICC 080	<i>Fusarium</i> , <i>Phytophthora</i> , <i>Pythium</i> , <i>Rhizoctonia</i> , <i>Sclerotinia</i>	Cucurbits, leafy vegetables, fruiting vegetables, herbs	
Prestop WP ^{OG} PVent ^{OG}	<i>Gliocladium catenulatum</i> Strain Ji1446	<i>Pythium</i> , <i>Phytophthora</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Verticillium</i> , <i>Botrytis</i>	Most crops. See label for crops registered for incorporated or drench treatment only.	
Rhapsody ^{OG}	<i>Bacillus subtilis</i> QST 713	<i>Alternaria</i> , bacterial blight (<i>Xanthomonas</i>), downy mildew, powdery mildew, <i>Sclerotinia</i> spp., <i>Botrytis</i> , rust, <i>Phytophthora infestans</i>	Broccoli, carrot, lettuce, onion, pepper, tomato, herbs	Greenhouse Use.
RootShield ^{OG}	<i>Trichoderma harzianum</i> Rifai Strain KRL-AG2	<i>Pythium</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Cylindrocladium</i> , <i>Thielaviopsis</i>	Eggplant, pepper, tomato, lettuce, crucifers, cucurbits, herbs, bulb crops	In-furrow treatment, greenhouse use
RootShield Plus ^{OG}	<i>Trichoderma harzianum</i> Rifai Strain T-22 & <i>T. viriens</i> Strain G-41	<i>Pythium</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Cylindrocladium</i> , <i>Thielaviopsis</i>	Eggplant, pepper, tomato, lettuce, crucifers, cucurbits, herbs, bulb crops	soilborne diseases, greenhouse use
Serenade Opti ^{OG} , Serenade ASO ^{OG}	<i>Bacillus subtilis</i> QST 713	<i>Alternaria</i> , Anthracnose, <i>Botrytis</i> , downy mildew, powdery mildew, rust, <i>Helminthosporium</i> diseases, <i>Didymella</i> , <i>Phoma</i> , Bacterial diseases	Most crops	Can also be used for postharvest disease protection
Sonata ^{OG}	<i>Bacillus pumilis</i> QST 2808	<i>Alternaria</i> , Downy mildew, Powdery mildew, Rust	Most crops	
Stargus ^{OG}	<i>Bacillus amyloliquefaciens</i> F727	<i>Fusarium</i> , <i>Phytophthora</i> , <i>Pythium</i> , <i>Rhizoctonia</i> , <i>Sclerotinia</i> , downy mildew, <i>Botrytis</i>	Most crops	
Subtalex NG	<i>Bacillus subtilis</i> MBI 600	<i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Pythium</i> , Powdery mildew	Pepper, tomato, eggplant, cucurbits	For greenhouse use only.
Taegro 2 ^{OG}	<i>Bacillus amyloliquefaciens</i> FZB24	<i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Sclerotinia</i> , <i>Pythium</i> , <i>Phytophthora</i> , leaf spots, Powdery mildew	Fruiting vegetables, cucurbits, leafy vegetables	In-furrow, transplant drench, basal spray for primarily soilborne diseases.
Triathlon BA ^{OG}	<i>Bacillus amyloliquefaciens</i> D747	<i>Botrytis</i> , <i>Rhizoctonia</i> , <i>Fusarium</i> , <i>Sclerotinia</i> , <i>Pythium</i> , <i>Phytophthora</i> , leaf spots, powdery mildew, downy mildew	Most crops	

Biological Insect Control

Biological control is taking place in vegetable crops all the time, because native and naturalized populations of natural enemies overwinter on the farm and move into crops to feed on or lay their eggs into pest insects. Predators consume several insects over the course of their development. Parasites (also called parasitoids) lay eggs in their host insect, which hatch into larvae that feed internally, develop, and kill the host. Pathogens invade the body of the host insect. The impact of beneficial insects is often underestimated because it is easy to overlook and difficult to measure. Beneficial insects may be killed by broad-spectrum insecticides, and pest outbreaks can occur as a result. Conservation of beneficials by use of selective insecticides when pests exceed threshold levels is recommended wherever practical.

The release of commercially produced beneficials can also aid in suppressing pests. These tend to be more successful in greenhouses than in the field, but there are several instances where releases in the field have been proven to suppress or completely control key pests. *Trichogramma* are tiny wasps that lay their eggs inside the eggs of insects, and wasp larvae develop inside, killing the egg. Several species are commercially available, but the most useful in vegetable crops are *T. pretiosum* for caterpillar eggs and *T. ostriniae* against European corn borer in sweet corn and pepper. Releases should be timed to coincide with egg laying. See Table 22 (page 78) for information about biological controls for the field, and also Biological Control for Insects and Mites in the Vegetable Transplants section.

Biological Disease Control

Biological disease control products (fungicides, bactericides, and nematicides) fall into the same classes as the insecticides. Botanicals, minerals, and synthetics are listed in Table 23. Sulfur, potassium bicarbonate, phosphites, and copper compounds are examples of minerals or synthetics that can control fungal and bacterial diseases. Not all of these products are OMRI listed; be sure to check with your state certifying authority for more information on these materials. Botanicals such as rosemary oil, soybean oil, or garlic extracts also appear in this table and are generally approved for use in organic production by OMRI. Products listed in Table 23 require thorough coverage, application at the first signs of disease, and frequently repeated dosages to be effective. For products that may be used in vegetable transplant production, see Table 19, page 54.

Microbial products are listed in Table 24 and are all living organisms which require specialized storage and application procedures. The table includes beneficial fungi and bacteria such as *Streptomyces*, *Gliocladium*, and *Trichoderma*, which compete with plant pathogens, produce toxic metabolites, or actively parasitize pathogens. Their effectiveness in university research trials has been inconsistent because of variations in environmental conditions and disease pressure. Microbial disease control products perform best in a greenhouse environment where they can establish and flourish. Control of plant pathogenic organisms on the phylloplane (leaf surface) is especially problematic, as the competing organisms must establish themselves and can fail due to desiccation and exposure to sunlight. These materials have a limited shelf life, must be protected from temperature

extremes, and correctly applied (plenty of water and under the correct environmental conditions) for effectiveness.

DISEASE MANAGEMENT

Plant diseases can result from a combination of many factors. Under certain conditions, viruses, nematodes, bacteria, fungi, heat, cold, chemicals and air pollution can all cause plant disease. By creating conditions that promote plant vigor, losses due to disease can be minimized.

- When diseases begin early in the season, yield and quality are more likely to be reduced. Always use disease-free seed, transplants, or cuttings.
- Use hot water and/or fungicide-treated seed where appropriate. Hot water treatment may prime the seeds to sprout; treatment should be done as close to planting as possible.
- Pasteurize seed bed soil and potting soils with steam or chemicals. Unopened bags of soilless media do not have to be treated.
- Disinfect pots, flats, tools and greenhouse surfaces before planting.
- Avoid the reintroduction of disease-causing organisms to disinfected soil.
- Do not let pathogens get a head start by practicing good sanitation. Destroy plant debris, trash piles, and weeds that harbor pathogens. Remove and destroy infected plants and plant parts when feasible. Practice crop rotation.
- Promote plant vigor. Do not overwater or plant in poorly drained soils. Use fertilizers, growth regulators, herbicides, insecticides, fungicides only as directed. Measure them accurately and apply them properly to avoid toxicity to the plants and yourself.
- Some healthy plants can succumb to disease. Select varieties that are resistant to the diseases that you know are a problem in your area.
- Purchase plants from a reputable source and protect plants from pathogens by following a suitable spray program. Knowing the diseases of your crop and the most effective time to begin spraying can save a crop and money.
- Air-blast sprayers can increase the spread of bacterial diseases.
- Effective control of plant disease depends upon accurate identification of the disease. Contact your regional or state Extension specialist or plant disease clinic (see Specimens for Disease Diagnosis, below).

Hot Water Treatment of Seed

Ideally, seed should be custom treated by request. If this is not possible, seed can be hot-water treated at home. UMass Extension offers a custom hot water seed treatment service: <https://ag.umass.edu/services/hot-water-seed-treatment>. Some lots of seed can be vulnerable to heat treatment. Always treat a small amount of seed (50 to 100) of each lot before treating the remainder of the lot. After the test treatment, air dry completely and then moisten for a germination test. Include untreated seed of the same lot for comparison. Treated seed should be used in the current season. Small seeded crops such as brassicas, carrot, pepper, etc. are the most appropriate for hot water treatment. Each seed type has a corresponding temperature and length of

time for treatment. Full instructions for treating seed on your own may be found here: <https://ag.umass.edu/vegetable/fact-sheets/hot-water-seed-treatment>.

Always check with the seed source to make sure it has not already been treated.

Specimens for Disease Diagnosis

Effective control of plant disease depends upon the accurate identification of the cause. Accurate and rapid diagnosis of a plant disease by diagnostic labs requires an examination of specimens that are representative of the disease, plus a review of information concerning the growing of the crop. The diagnosis and recommendations reported to the grower are based on this information. Plants in advanced stages of decay or desiccation, or those that arrive with no case history information, cannot be diagnosed properly. Before sending the specimen, contact your regional or state Extension specialist or plant disease clinic. Deliver the specimen by overnight mail. Some states may charge a fee for diagnostic services. Supply as much of the following information as possible:

- Your name, address, zip code, phone number and e-mail address.
- Crop, cultivar, and date collected.
- Planting size (acres) or number of plants.
- Percentage of plants diseased.
- Distribution of disease (general or all over field, scattered here and there, or localized in a small area of field).
- Symptoms you are concerned about (blight, wilt, stunt, death, yellowing, leaf mottle, stem rot, root rot, fruit rot, leaf spot, die back, etc.).
- Chemicals applied, including dates and rates of fertilizers, fungicides, nematicides, herbicides, and growth regulators.
- Any information that you believe may be important about the circumstances leading to the disease.

Virus Diseases

Many different viruses can infect vegetable crops. Some, like Papaya Ringspot Virus-W, have a narrow host range, while others, like Cucumber Mosaic Virus and Tomato Spotted Wilt Virus, infect a wide variety of vegetable crops as well as ornamentals and weeds. Symptoms of virus infection are most evident on foliage and fruit. However, the symptoms are not always unique to viruses and may closely resemble nutritional disorders, herbicide injury, or insect feeding. A subtle but common symptom of virus infection is an overall stunting and reduction in yield.

Viruses are spread in a variety of ways. Mechanical transmission through handling of plants or use of contaminated tools is an efficient means of spreading Tobacco Mosaic Virus and Potato Virus X. Most viruses, however, are not spread in this manner. Insects such as aphids, thrips, mites, leafhoppers, and beetles provide the most important means for viruses to move from infected to healthy plants. Some viruses, such as Tomato Ringspot Virus and Squash Mosaic Virus, can be transmitted through infected seed. Perennial weeds and ornamental hosts provide an important reservoir for viruses to survive from one season to the next.

Aphids are the most important primary and secondary vectors of virus diseases. Depending on their relationship with the aphid, viruses are classified as either persistent or non-persistent. Intermediate forms also exist. Aphids that acquire persistent viruses do so after a minimum feeding time of 10 to 60 minutes. Following acquisition, a latency period of at least 12 hours must pass before the aphid can transmit the virus. The aphid remains infective for at least a week, or in some cases, for its entire life. With non-persistent viruses, the aphid can pick up the virus rapidly (within seconds or minutes) while probing the host tissue and can transmit the virus immediately to another plant. However, the ability of the aphid to successfully transmit the virus is quickly lost (within minutes). Insecticides increase the spread of non-persistent viruses by stimulating probing activity of the aphid. Contact insecticides are generally less useful than systemics for controlling insect-vectored viruses.

In general, the spread of viruses is best controlled by cultural practices such as cultivar selection, planting date and location, weed reduction, and roguing of diseased plants. Row covers may prevent aphids from probing and feeding on plants early in the season preventing the spread of viruses. Occasionally, seed or transplants are infected and the problem is not apparent until well into the growing season. There are no chemical control measures for virus diseases other than those directed at the vector or weed hosts. For more specific control measures, refer to the crop.

Fungicides and Bactericides

Fungicides and bactericides are used to prevent, not cure diseases. Applications initiated before disease appears or at the first sign of disease, are the most effective way to use these pesticides. Knowledge of the cause of the disease is required to select the proper material. Your regional and state specialist can assist you in determining the cause (see Specimens for Disease Diagnosis, above). Note that the continuous use of certain bactericides or fungicides can result in pathogens becoming resistant to these chemicals.

For detailed information about fungicides and bactericides, see Tables 23, 24 and 25 on pages 79, 80, and 84 respectively.

Resistance Management

Pathogens that survive an application of a fungicide are likely to pass the trait that enabled them to survive on to their offspring. A single genetic change in the pathogen can render single-site mode of action (systemic) fungicides ineffective. Repeated applications of the same type of fungicide exert selection pressure on the pathogen population and eventually eliminate almost all the susceptible individuals from a pest population. Resistance can develop in a very short time.

It is necessary to practice resistance management to preserve the useful life of a fungicide. The most effective way to extend the useful life of an product is to use it once and then alternate with a fungicide with a different mode of action. Fungicides are grouped according to chemical class or site of their activity and assigned a group number by the Fungicide Resistance Action Committee (FRAC Group). To select fungicides with different modes of action, see resistance group (FRAC) in Table 25 (page 84) and in the following section Fungicides and Bactericides Alphabetical Listing by Trade Name. Fungicides that are systemic (penetrant) have a

single site of action upon the target organisms' physiology and are particularly prone to developing resistance. Use systemic fungicides with a single site of action once per season. Use the most effective chemical against a particular pest first. Do not apply fungicides with a high risk of resistance development (systemic, single mode of action such as Group 11 strobilurins) when disease is severe as this situation results in high selection pressure upon the pathogen.

There are many other techniques that can help delay the onset of resistance. Many resistance management techniques help minimize the use of pesticides so a lower proportion of each pest generation is exposed to the toxin.

- Integrate chemical controls with effective cultural, mechanical, physical, and genetic management options.
- Scout, monitor, and use action thresholds to determine if fungicide applications are necessary.
- Good spray coverage helps do the job right the first time and avoids unnecessary repeat applications: use the proper size nozzles at the correct angle or orientation and an adequate amount of water per acre.
- Tank mixes of systemic materials with contact fungicides help delay the onset of resistance to the systemic fungicides. Most contact fungicides have a multi-site mode of action (FRAC Group M plus a number).

NOTE: There is no relationship between insecticide groups, herbicide groups, and fungicide groups. For example, there is no problem using a Group 1 herbicide and a Group 1 insecticide or fungicide.

Toxicity of Fungicides

All pesticides are poisonous. However, some are more toxic than others. The toxicity of the pesticide is usually stated in the precaution on the label. For example, a skull and crossbones figure and the signal word "Danger" are always found on the label of highly toxic (Toxicity Class I) materials. Those of medium toxicity (Toxicity Class II) carry the signal word "Warning." The least toxic materials (Toxicity Class III) have the signal word "Caution." The toxicity of a pesticide is expressed in terms of oral and dermal LD₅₀. LD₅₀ is the dosage of poison that kills 50% of test animals (usually rats or rabbits) with a single application of the pure pesticide for a given weight of the animal (mg/kg of body weight). **The lower the LD₅₀ value, the more toxic the material.** Oral LD₅₀ is the measure of the toxicity of pure pesticide when administered internally to test animals. Dermal LD₅₀ is the measure of the toxicity of pure pesticide applied to the skin of test animals. Generally, an oral application is more toxic than a dermal one.

Fungicides and Bactericides Alphabetical Listing by Trade Name

The symbol ⁰⁶ indicates a pesticide that has been listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. REI = Re-Entry Interval expressing hours (h). At the time of writing, all products listed were registered in at least one New England state. Check registration status in your state before using any product.

3336 F (thiophanate-methyl): A systemic fungicide with broad spectrum control. Also labeled for greenhouse transplants. REI 12h, Group 1

42-S Thiram (thiram): A seed treatment with a wide host range. REI 24h, Group M3

Actigard 50 WG (acibenzolar-S-methyl): Plant defense activator used for bacterial diseases and Downy Mildews. REI 12h, Group 21

Actino-Iron⁰⁶ (Streptomyces lydicus WYEC): Biological soil and seed treatment for *Fusarium*, *Rhizoctonia*, *Pythium*, and *Phytophthora* with added iron. REI 4h, Group NC

Actinovate AG (Streptomyces lydicus): Biological for greenhouse use only in vegetable crops. REI 1h, Group NC

Agclor 310 (sodium hypochlorite): A commercial bleach solution registered for use to control postharvest rots of vegetables. Group NC

Affirm WDG (polyoxin-D): Broad-spectrum fungicide for foliar and soilborne diseases. May be used in greenhouse. REI 4h, Group 19

Agri-Fos (phosphorus acid): A fungicide active against *Pythium*, *Phytophthora*, and downy mildew. REI 4h, Group 33

Agri-mycin 17 (streptomycin sulfate): A bactericide. REI 12h, Group 25

Aliette WDG (fosetyl AI): A fungicide active against *Pythium*, *Phytophthora*, and downy mildew. REI 12h, Group 33

Alude (phosphorous acid): A fungicide active against *Pythium*, *Phytophthora*, and downy mildews labeled for greenhouse transplant production. REI 4h, Group 33

Apron XL (mefenoxam): A seed treatment against *Pythium* and *Phytophthora* seed rot and damping-off and systemic downy mildews of certain crops. REI 48h, Group 4

Aprovia Top (benzovindiflupyr + difenoconazole): For many diseases of cucurbits, legumes, peppers, tomatoes, sweet potato. REI 12h, Groups 3 & 7

Ariston (chlorothalonil + cymoxanil): Labeled for several diseases on several crops. REI 12h (see label), Groups M5 & 27

BadgeX2⁰⁶ SC (copper oxychloride + copper hydroxide): A bactericide and fungicide. REI 24h, Group M1

Basic Copper 53⁰⁶ (basic copper sulfate): A broad spectrum fungicide. REI 48h, Group M1

Bio-Save 10 LP⁰⁶ (Pseudomonas syringae ESC-10): Postharvest decay of potato. Group NC

Bio-Tam⁰⁶ (Trichoderma aperellum, T. gamsii): Biological soil treatment for most crops. REI 4h Group BM02

Blocker 4F (PCNB): Soil-borne diseases of brassicas, beans and peas, garlic, tomatoes, and pepper. REI 12h, Group 14

BotryStop⁰⁶ (Ulocladium oudemansii U3 Strain): A biological control for *Botrytis* and *Sclerotinia* diseases. REI 4h, Group NC

Bumper (propiconazole): Diseases of corn, celery, carrot, chard and bulb crops. REI 12h, Group 3

Bravo (Weather Stik, Ultrex, ZN) (chlorothalonil): A broad spectrum fungicide. REI 12h, Group M5

Cabrio EG (pyraclostrobin): A broad spectrum fungicide for bulb, cucurbit, fruiting, and root vegetables. REI 12h, Group 11

Cabrio Plus (pyraclostrobin + metiram): For management of certain diseases of potato. REI 24h, Groups 11 & M3

Camelot O⁰⁶ (copper soap): Copper product labeled for greenhouse use on vegetable transplants. REI 4h, Group M1

Table 25: Information about Fungicides and Bactericides

Active Ingredient	Signal Word ^e	Trade Name	Resistance Group ^b (FRAC code)	Dermal LD ₅₀ , mg/kg	Oral LD ₅₀ , mg/kg
ametoctradin & dimethomorph	C	Zampro	45 & 40	>5,000	>500 <2,000
azoxystrobin	C	Quadris, Dynasty	11	>2,000 - 4,000	>2,000 - 5,000
azoxystrobin & chlorothalonil	W	Quadris Opti	11 & M5	>5,000	1,750
azoxystrobin & difenoconazole	C	Quadris Top	11 & 3	>2,000	>2,000
azoxystrobin & flutriafol	C	Topguard EQ	11 & 3	>5,000	>5,000
azoxystrobin & mefenoxam	C	Ridomil Gold SL	11 & 4	>4,000	>5,000
azoxystrobin & propiconazole	W	Quit, Quit Xcel, Trivapro B	11 & 3	>5,000	1,750 / 1030
azoxystrobin & tebuconazole	W	Custodia	11 & 3	>2,000	>300
benzovindiflupyr	D	Trivapro A	7	>5,000	550
benzovindiflupyr & difenoconazole	W	Aprovia Top	3 & 7	>5,000	1,750
benzovindiflupyr & azoxystrobin & propiconazole	W	Trivapro	7 & 11 & 3	>2,000	550
boscalid	W	Endura	7	>2,000	>2,000
chlorine	D	Agclor 310	NC	>20,000	8,910
chlorothalonil	C, W	Bravo Weather Strik, Bravo Ultrex, Bravo Zn, Echo 720, Echo 90 DF, Equus 720 SST, Initiate 720, Initiate Zn, Orondis Opti B	M5	>2,000 - 10,000	>3,750 - 10,000
chlorothalonil & cymoxanil	C	Ariston	M5 & 27	>5,050	>5,000
chlorothalonil & oxathiapiprolin	D	Orondis Opti	M5 & 49	>2,000	>5,000
copper hydroxide	C, D	Champ WG ⁰⁶ , Champ Dry Prill, Champ Formula 2 Flowable, Kalmor ⁰⁶ , Kocide 2000, Kocide 2000-0 ⁰⁶ , Kocide 3000, Kocide 3000-0 ⁰⁶ , ChampION+ ⁰⁶ , Nu-Cop 60DF ⁰⁶ , 50Wp ⁰⁶ , HB ⁰⁶ , Kentan DF	M1	1,300->5,000	489-1,847
copper hydroxide & copper oxychloride	W	Badge X2 ⁰⁶	M1	>2,000	>300
cuprous oxide	C	Nordox 75 WG ⁰⁶	M1	>2,000	3,165
copper octanoate	C	Camelot O, Cueva	M1	>2,000	>2,000
copper oxychloride and copper hydroxide	C, W	Badge SC, Badge X2	M1	>300	>2,000
copper sulfate (basic copper)	C, W, D	Basic Copper 53 ⁰⁶ , Cuprofix Ultra, Cuproxat FL ⁰⁶ , Cuproxat, Phytton 35, MasterCop ⁰⁶	M1	>2,000-8000	1,000-2,521
cyazotamid	C	Ranman, Ranman 400 SC	21	>2,000	>5,000
cyflufenamid	C	Torino	U6	>2,000	<2,000
cymoxanil	W	Curzate 60 DF	27	>2,000	>433
cyprodinil & fludioxonil	C	Switch 62.5	9 & 12	>2,000	>5,000
difenoconazole & cyprodinil	C	Inspire Super	3 & 9	>5,000	5,000
dimethomorph	C	Forum	15	>2,000	>5,000
famoxadone & cymoxanil	C	Tanos	11 & 27	>2,000	>5,000
fenamidone	C	Reason 500 SC	11	>5,000	>5,000
fenhexamid	C	Decree 50 WDG	17	>2,000	>2,000
fluazinam	W	Omega 500F, Omega TopMP	29	>2,000	>5,000
fludioxonil	C	Maxim4FS, Maxim PSP, Cannonball WG, Emblem	12	>2,020	1,971
fludioxonil & mancozeb	C	Maxim MZ	12 & M3	>5,000	>5,000
fluopicolide	C	Presidio	43	>4,000	>2,000
fluopyram	C	Velum Prime	7	>2,000	>2,000
fluopyram & pyrimethanil	C	Luna Tranquility	7 & 9	>2,000	>2,000
fluopyram & tebuconazole	C	Luna Experience	7 & 3	>2,000	>2,000
fluopyram & trifloxystrobin	C	Luna Sensation	7 & 11	>2,000	>2,000
fluto lanil	C	Moncut 70 DF	7	>5,000	>5,000
fluto lanil & mancozeb	C	Moncoat MZ	7 & M3	>5,000	>5,000
flutriafol	C	Topguard Fungicide, Rhyme	3	>2,000->5,000	>2,000
fluxapyroxad & pyraclostrobin	C	Priaxor, Merivon	7 & 11	>5,000	>300->2,000
fosetyl aluminum	C	Aliette WDG	33	2,000	>5,050
hydrogen peroxide & peroxyacetic acid	D	Oxidate 2.0 ⁰⁶ , ZeroTol 2.0 ⁰⁶	NC	1,040	3,622

Table 25: Information about Fungicides and Bactericides (continued)						
Active Ingredient	Signal Word ^a	Trade Name	Resistance Group ^b (FRAC code)	Dermal LD ₅₀ , mg/kg	Oral LD ₅₀ , mg/kg	
iprodione	C	Iprodione 4L AG, Rovral 4F, Nevado 4F	2	1,170 - 2,000	2,000 - 2,860	
mancozeb	C	Penncozeb (75DF, 80WP), Manzate (Max, Pro-Stick), Dithane (M-45, F-45 Rainsshield), Potato Seed Treater (6%, PS), Roper (DF, DF Rainsshield)	M3	>2,000	>5,000	
mancozeb & copper	D	ManKocide	M3 & M1	>5,000	2,535	
mandipropamid	C	Revus, Micora, Orondis Ultra B	40	>5,000	>5,000	
mandipropamid & difenoconazole	C	Revus Top	3 & 40	>5,000	2,958	
mefenoxam	C	Ridomil Gold (GR, SL), Apron XL, Ultra Flourish	4	2,020	1,172	
mefenoxam & chlorothalonil	W	Ridomil Gold Bravo SC	4 & M5	>2,020	1,172	
mefenoxam & copper	D	Ridomil Gold Copper	4 & M1	2,020	560	
mefenoxam & mancozeb	C	Ridomil Gold MZ WG	4 & M3	>2,000	>5,000	
metconazole	C	Quash	3	>5,000	1,750	
metrafenone	C	Vivando	U8	>5,000	>5,000	
metiram	C	Polyram 80 DF	M3	>2,000	>5,000	
myclobutanil	W	Rally	3	>5,000	1,870	
oxathiapiprolin	C	Orondis (Ultra A, Gold 200, Opti A)	49	>5,000	>5,000	
oxathiapiprolin & mandipropamid	C	Orondis Ultra	49 & 40	>5,000	>5,000	
PCNB	C	Blocker (4F, 10G), Terraclor 400	14	>2,020	>5,050	
penthiopyrad	C	Fontelis	7	>5,000	>5,000	
phosphorus acid (salts of)	C	Agri-Fos, Alude, Fosphite, KPhite, Phostrol, ProPhyt, Rampart, Reveille	33	>2,000	>5,000	
polyoxin D	C	Oso 5% SC, Ph-D, Affirm WDG	19	>2,000	4,916	
potassium bicarbonate	C	Kaligreen ⁰⁶ , MilStop ⁰⁶	NC	>5,000	2,700	
potassium dihydrogen phosphate	C	Nutral	NC			
propamocarb	C	Previcur Flex	28	>3,920	2,000-8,550	
propiconazole	W	Tilt, PropiMax EC, Bumper (41.8EC & ES)	3	>5,000	1,310	
propiconazole & trifloxystrobin	W	Stratego	3 & 11	>5,050	4,757	
prothioconazole	C	Proline 480SC	3	>5,000	>2,000-<5,000	
prothioconazole & trifloxystrobin	W	Stratego YLD	3 & 11	>5,000	>5,000	
pyraclostrobin	C, W	Headline, Headline SC, Cabrio EG	11	200 - >2,000	2,000 - 4,000	
pyraclostrobin & boscalid	C	Pristine, Pageant Intrinsic	11 & 7	>2,000	1,490	
pyraclostrobin & metconazole	W	Headline AMP	11 & 3	>5,000	500	
pyraclostrobin & metiram	C	Cabrio Plus	11 & M3	>2,000	> 500-<2,000	
pyrimethanil	C	Scala SC	9	>5,000	4,505	
quinoxifen	C	Quintec	13	>2,000	>2,000	
streptomycin	C	Agri-Mycin 17	25	>2,000	>5,000	
sulfur	C	Microthiol Dispers ⁰⁶ , Kumulus DF ⁰⁶ , Sulfur 6L, Microfine Sulfur	M2	>2,000	>2,000	
tebuconazole	C	Orius 3.6F	3	>2,000	>2,000	
tetraconazole	C	Mettle 125 ME	3	>2,000	>4,090	
thiabendazole	C	Mertect 340-F	1	>5,050	>5,000	
thiophanate-methyl	C	Topsin M WSB, Topsin 4.5 FL, Nufarm T-Methyl (70WSB, 4.5F), Incognito (4.5 F, 85 WDG)	1	>2,000	>5,000	
triphenyltin hydroxide	D	Super Tin (80 WP, 4L)	30	500	160	
trifloxystrobin	C	Flint Extra, Gem 500 SC	11	>2,000	>5,050	
triflumizole	C	Procure 480 SC, Trionic 4SC	3	>5,000	>1,400	
thiram	C	42-S Thiram	M3	>4,400	2,950	
zoxamide & chlorothalonil	C	Zing!	22 & M5	>5,000	1,750-5,000	
zoxamide & mancozeb	C	Gavel 75 DF	22 & M3	>5,000	>5,000	

^a C = Caution; W = Warning; D = Danger
^b FRAC = Fungicide Resistance Action Committee group
 The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification section for more details. Note that for a given active ingredient, some products may be OMRI listed while others are not.

Cannonball WG (fludioxonil): For management of *Sclerotinia*, *Botrytis* and other pathogens on onions and beans. REI 12h, Group 12

Catamaran (potassium phosphite + chlorothalonil): Broad spectrum fungicide and plant activator. REI 12h, Groups 33 & M5

Cease⁰⁶ (*Bacillus subtilis* QST 713): Biological protectant fungicide. REI 4h, Group 44

Champ WG⁰⁶ (copper hydroxide): Copper fungicide. REI 48h, Group M1

Champ Dry Prill (copper hydroxide): Copper fungicide. REI 24/48h, Group M1

Champ Formula 2 Flowable (copper hydroxide): Copper fungicide. REI 48h, Group M1

Champion++ (copper hydroxide): Copper fungicide. REI 48h, Group M1

Companion⁰⁶ (Liquid, WP) (*Bacillus subtilis* strain GB03): Biological fungicide. REI 4h, Group 44

Contans WG⁰⁶ (*Coniothyrium minitans*): For *Sclerotinia sclerotiorum* and *Sclerotinia minor* diseases. (Bayer formula not labeled for tomato). Group NC

Cuprofix Ultra 40 Disperss (basic copper sulfate): A broad spectrum fungicide. REI 48h, Group M1

Cuproxat, Cuproxat FL⁰⁶ (basic copper sulfate): A broad spectrum fungicide. REI 48h, Group M1

Curzate 60 DF (cymoxanil): For late blight of potato and tomato and downy mildew of cucurbits and lettuce. REI 12h, Group 27

Custodia (azoxystrobin + tebuconazole): A broad spectrum fungicide labeled for foliar diseases of corn. REI 12h (for corn), Groups 3 & 11

DiTera DF⁰⁶ (*Myrothecium verrucaria* Strain AARC-0255): For management of plant parasitic nematodes. REI 4h, Group NC

Dithane (M-45, F-45 Rainshield) (mancozeb): A broad spectrum, protectant fungicide. REI 24h, Group M3

Decree 80 WDG (fenhexamid): *Botrytis* control in greenhouse transplants. REI 12h, Group 17

Double Nickel⁰⁶ 55 and LC (*Bacillus amyloliquefaciens*): Microbial fungicide. REI 4h, Group 44

Dynasty (azoxystrobin): A broad spectrum seed treatment fungicide for diseases of seed-borne diseases. REI 4h, Group 11

Echo (90DF, 720) (chlorothalonil): A broad spectrum fungicide. REI 12h, Group M5

EcoSwing⁰⁶ (extract of *Swinglea glutinosa*): Preventive biological fungicide for *Alternaria* leaf spot, *Botrytis*, and powdery mildew on many crops. Also labeled for greenhouse use. Activates ISR (induced systemic resistance). REI 12h, Group NC

Emblem (fludioxonil): For greenhouse use only on plants and transplants of listed crops. REI 12h, Group 12

Endura (boscalid): A protectant fungicide for legumes, brassicas, bulb vegetables, fruiting vegetables, lettuce, and root and tuber vegetables. REI 12h, Group 7

Equus 720 SST (chlorothalonil): A broad spectrum fungicide. REI 12h, Group M5

Flint (trifloxystrobin): A strobilurin fungicide with broad-spectrum activity. REI 12h, Group 11

Fontelis (penthiopyrad): A fungicide with broad host clearance for leaf spots, blights, anthracnose, and *Sclerotinia* diseases. REI 12h, Group 7

Forum (dimethomorph): A fungicide for use against *Phytophthora* and downy mildew of bulb, cucurbit and fruiting vegetables, lettuce, potatoes, and tomatoes. REI 12h, Group 40

Fosphite (phosphorus acid): A phosphorous acid fungicide active against *Pythium*, *Phytophthora*, and downy mildew. REI 4h, Group 33

Gavel (75 DS, DF) (zoxamide + mancozeb): A broad-spectrum protectant fungicide for disease control in potatoes, cucurbits, and tomatoes. REI 48h, Groups 22 & M5

GEM 500 SC (trifloxystrobin): Broad spectrum fungicide. REI 12h, Group 11

Headline, Headline SC (pyraclostrobin): A broad spectrum, strobilurin fungicide for use in legumes, corn, tuberous and corn vegetables. REI 12h, Group 11

Headline AMP (pyraclostrobin + metconazole): For diseases of corn. REI 48h, Groups 11 & 3

Heritage (azoxystrobin): Preventative and curative broad-spectrum fungicide. See supplemental label for use on vegetable transplants grown in the greenhouse. REI 4h, Group 11

Incognito (4.5 F, 85 WDG) (thiophanate-methyl): A systemic fungicide with broad spectrum control. REI (Varies with crop, see label) Group 1

Initiate (720, ZN) (chlorothalonil): A broad spectrum fungicide. REI 12h, Group M5

Inspire Super (difenoconazole + cyprodinil): For powdery mildew. REI 12h, Groups 7 & 9

Iprodione 4L AG (Iprodione): For *Alternaria*, *Botrytis* and *Rhizoctonia* diseases; sclerotinia diseases; in beans, broccoli, carrots, dry bulb onions, and lettuce; white rot of garlic, . REI 24h, Group 2

JMS Stylet-Oil⁰⁶, JMS Stylet-Oil (paraffinic oil): Fungal diseases and aphid transmitted viruses. Also labeled for greenhouse use. REI 4h, Group NC

Kaligreen⁰⁶ (potassium bicarbonate): Powdery mildew and other foliar diseases. REI 4h, Group NC

Kalmor⁰⁶ (copper hydroxide): Broad spectrum bactericide and fungicide. REI 48h, Group M1

Kentan DF (copper hydroxide): Broad spectrum bactericide and fungicide. REI 48h, Group M1

K-Phite 7LP (phosphorus acid): *Pythium*, *Phytophthora*, and downy mildew; also labeled for greenhouse transplant production. REI 4h, Group 33

Kocide 2000, Kocide 2000-0⁰⁶, Kocide 3000, Kocide 3000-00G (copper hydroxide): Broad spectrum bactericide and fungicide. REI 48h, Group M1

Kumulus DF⁰⁶ (sulfur): Broad spectrum fungicide, particularly for powder mildew. REI 24h, Group M2

Luna Experience (fluopyram + tebuconazole): Fungal diseases on watermelon only. REI 12h, Groups 3 & 7

Luna Sensation (fluopyram + trifloxystrobin): Foliar and soilborne diseases of several crops. REI 12h, Groups 7 & 11

Luna Tranquility (fluopyram + pyrimethanil): For fungal diseases of potato. REI 12h, Groups 7 & 9

ManKocide (copper + mancozeb): A broad spectrum fungicide and bactericide. REI 48h, Groups M3 & M1

Manzate (Max, Pro-Stick) (mancozeb): A broad spectrum fungicide. REI 24h, Group M3

MasterCop (copper sulfate pehtahydrate): A broad spectrum fungicide and bactericide. REI 48h, Group M1

Maxim 4FS (fludioxonil): A seed treatment fungicide for seed-borne and soil-borne fungi of several vegetable crops. REI 12h, Group 12

Maxim MZ (fludioxonil + mancozeb): A seed treatment fungicide for certain diseases of potato. REI 12h, Group 12

Maxim PSP (fludioxonil): A seed treatment fungicide for certain diseases of potato. REI 12h, Group 12

Merivon (fluaxapoxad + pyraclostrobin): For fungal diseases including powdery mildew. REI 12h, Groups 7 & 11

Mertect 340-F (thiabendazole): A seed treatment for fungal seed-borne and soil-borne diseases. REI 12h, Group 1

Micora (mandipropamid): Oomycete fungicide labeled for greenhouse use. REI 4h, Group 40

Microthiol Disperss⁰⁶ (sulfur): A protectant fungicide particularly useful for powdery mildew. May be used in greenhouse. REI 24h, Group M2

Microfine Sulfur (sulfur): A protectant fungicide particularly useful for powdery mildew. REI 24h, Group M2

Micro Sulf⁰⁶ (sulfur): A protectant fungicide particularly useful for powdery mildew. May be used in greenhouse. REI 24h, Group M2

Mildew Cure⁰⁶ (cottonseed, corn, and garlic oils): For powdery mildew. Group NC

MilStop⁰⁶ (potassium bicarbonate): Powdery mildew and other foliar diseases of greenhouse crops. REI 1h, Group NC

M-Pede⁰⁶ (insecticidal soap): Insecticide/fungicide labeled for greenhouse use. REI 12h

Moncoat MZ (flutolanil + mancozeb): Potato seed piece treatment for late blight. REI 24h, Groups 7 & M3

Moncut 70 DF (flutolanil): For control of soil-borne fungal diseases of brassicas and potatoes. REI 12h, Group 7

Mural (azoxystrobin & benzovindiflupyr): Broad-spectrum fungicide for foliar applications for greenhouse-grown vegetable transplants grown for resale to consumers - cucurbits, fruiting vegetables, tomatoes. NOT for transplants intended for commercial field use. REI 12h, Group 11 and 7

Mycostop⁰⁶ (*Streptomyces griseoviridis* K61): Biological seed or soil treatment. REI 4h, Group NC

Nevado (Iprodione): For *Alternaria*, *Botrytis*, *Rhizoctonia* and *Stemphylium* diseases; sclerotinia diseases; in beans, broccoli, carrots, crucifers, dry bulb onions, potatoes, and lettuce; white rot of garlic. REI 24h, Group 2

Nordox 75 WGOG (cuprous oxide): Copper fungicide. REI 12h, Group M1

Nu-Cop (3L, 50DFOG, 50WP⁰⁶, HB⁰⁶) (copper hydroxide): Copper fungicide. REI 48h, Group M1

Nutrol (potassium dihydrogen phosphate): Protectant fungicide for powdery mildew. REI 4h, Group 33

Nufarm T-Methyl 70WSB, 4.5F (thiophanate-methyl): A systemic fungicide with broad spectrum control. REI (varies with crop, see label) Group 1

Obtego⁰⁶ (*Trichoderma aperellum*, *T. gamsii*): Biological soil treatment for most crops. REI 4h, Group BM02

Omega 500 (fluazinam): *Phytophthora* disease, downy mildew, leaf spots, *Sclerotinia* and *Sclerotium* diseases; late blight and white mold of potatoes. REI 48h, Group 29

Omega Top MP (fluazinam): Late blight and white mold of potatoes. REI 12h, Group 29

Organocide⁰⁶ (sesame oil): Powdery mildew. Group NC

Orius (3.6F) (tebuconazole): For onion diseases, and rusts, Powdery mildew, and other fungal diseases of select crops. REI (varies with crop, see label) Group 3

Orondis Opti (chlorothalonil + oxathiapiprolin): Diseases of cucurbits and fruiting vegetables. REI 12h, Groups M5 & 49

Orondis Opti B (chlorothalonil): A broad spectrum fungicide. REI 12h, Group M5

Orondis (Ultra A, Gold 200, Opti A) (oxathiapiprolin): *Phytophthora* diseases and downy mildew in several crops. REI 4h, Group 49

Orondis Ultra (oxathiapiprolin + mandipropamid): *Phytophthora* diseases and downy mildew in several crops. REI 4h, Groups 49 & 40

Orondis Ultra B (mandipropamid): *Phytophthora* diseases and downy mildew in several crops. REI 4h, Group 4

OSO 5% SC (polyoxin D): Broad spectrum fungicide for foliar and soilborne diseases. REI 4h, Group 19

OxiDate 2.0⁰⁶ (hydrogen dioxide + peroxyacetic acid): Preventive bioicide. REI 0-1h (see label), Group NC

OxiPhos (phosphorus acid + hydrogen peroxide): Preventive bioicide. REI 4h, Groups 33 & NC

Pageant Intrinsic (pyraclostrobin + boscalid): For diseases of greenhouse-grown cucurbits, fruiting vegetables, and leafy greens; and cucurbit, fruiting vegetable, and leafy green transplants for the home consumer market only (NOT for transplants for commercial field production). REI 12h, Groups 7 & 11

Penncozeb (75DF, 80WP) (mancozeb): A broad spectrum fungicide. REI 24h, Groups M3

PhD (polyoxin D): Broad spectrum fungicide for foliar and soilborne diseases. REI 4h, Group 19

Phyton 35 (copper sulfate): Copper sulfate product labeled for greenhouse use on vegetable transplants. REI 48/24h, Group M1

Phostrol (phosphorus acid): A fungicide for *Pythium*, *Phytophthora*, and Downy Mildew. REI 4h, Group 33

Polyram 80 DF (metiram): For early and late blight in potatoes. REI 24h, Group M3

Potato Seed Treater 6% (mancozeb): Potato seed piece treatment for Fusarium dry rot. REI 24h, Groups M3

PreFence⁰⁶ (*Streptomyces griseoviridis* K61): Biological seed or soil treatment. REI 4h, Group NC

Presidio 4SC (fluopicolide): A locally systemic fungicide effective against *Phytophthora* and Downy Mildews of bulb, cucurbit, fruiting, and leafy vegetables. REI 12h, Group 43

PreStop⁰⁶ (*Gliocladium catenulatum* J1446): Preventative biological fungicide that can be incorporated into media, applied as a drench or as a foliar spray. REI 4h, Group NC

Previcur Flex (propamocarb): A fungicide for Oomycetes. Previcur should be mixed with Bravo, Maneb or Mancozeb to prevent development of resistance. REI 12h, Group 28

Priaxor (fluxapyroxad + pyraclostrobin): For disease control and in beans, tomato, peas, potato and corn. REI 12h, Group 7 & 11

Pristine (boscalid + pyraclostrobin): For use in bulb vegetables, carrots, cucurbits and celery. REI 12h, Group 7 & 11

PVent⁰⁶ (*Gliocladium catenulatum* J1446): Preventative biological fungicide that can be incorporated into media, applied as a drench or as a foliar spray. REI 4h, Group NC.

Procure (triflumizole): Powdery mildew on brassica, cucurbits, and leafy vegetables. REI 24h, Group 3

Proline 480SC (prothioconazole): For diseases of corn, cucurbits, peas, and beans. REI 12h, Group 3

ProPhyte (phosphorus acid): Labeled for *Pythium*, *Phytophthora*, downy mildew. REI 4h, Group 33

PropiMax EC (propiconazole): Diseases of Allium species. REI 12h, Group 3

Quadris (azoxystrobin): A strobilurin fungicide with broad spectrum activity. REI 4h, Group 11

Quadris Opti (azoxystrobin + chlorothalonil): Broad spectrum fungicide for dry beans, cucurbit vegetables, potatoes, tomatoes, and onions. REI 12h, Group 11 & M5

Quadris Ridomil Gold (azoxystrobin + mefenoxam): Labeled for potatoes only. REI 0h, Group 11 & 4

Quadris Top (azoxystrobin + difenaconazole): Broad spectrum fungicide. REI 12h, Group 11 & 3

Quash (metraconazole): For management of several diseases, including white mold, in beans, potato and sweet potato. REI 12h, Group 3

Quilt (azoxystrobin + propiconazole): Broad spectrum fungicide for use in carrots, celery, corn, and bulb crops. REI 12h, Group 11 & 3

Quilt Xcel (azoxystrobin + propiconazole): Broad spectrum fungicide for use in carrots, celery, corn, and bulb crops. REI 12h, Group 11 & 3

Quintec (quinoxifen): Fungicide for control of powdery mildew in cucurbits. REI 12h, Group 13

Rally 40 SWP (myclobutanil): A fungicide for powdery mildews and rusts of vegetable crops. REI 24h, Group 3

Rampart (phosphorus acid): Labeled for *Pythium*, *Phytophthora*, downy mildew. REI 4h, Group 33

Ranman (cyazofamid): Effective against *Phytophthora* and downy mildew in cucurbits, tomatoes, bulb crops, and potatoes. REI 12h, Group 21

Reason 500 SC (femadione): A fungicide for use against *Phytophthora*, downy mildew, and white rust on tuberous and corm vegetables, tomatoes, bulb vegetables, lettuce, and cucurbit vegetables. REI 12h, Group 11

Regalia⁰⁶ (extract of *Reynoutria sachalinensis*): Plant defense activator for fungal and bacterial diseases. REI 4h, Group P5

Reville (phosphorus acid): Labeled for *Pythium*, *Phytophthora*, downy mildew. REI 4h, Group 33

Resist (phosphorus acid): Labeled for *Pythium*, *Phytophthora*, *Fusarium*, *Rhizoctonia*, downy mildew and silver scurf in potatoes. REI 4h, Group 33

Revus (mandipropamid): For use against downy mildew on peppers, brassica, bulb crops, cucurbits, and leafy vegetables. REI 12h, Group 40

Revus Top (mandipropamid + difenoconazole): Broad spectrum fungicide for potatoes and tomatoes. REI 12h, Groups 3 & 40

Rhyme (flutriafol): Labeled for several diseases on several crops. REI 12h, Group 3

Ridomil Gold (4SL, GR) (mefenoxam): A fungicide active against *Pythium*, *Phytophthora*, and the downy mildews. REI 48h, Group 4

Ridomil Gold Bravo SC (mefenoxam + chlorothalonil): Broad spectrum fungicide containing 4.4% metalaxyl and 72% chlorothalonil effective against both lower and true fungi. REI 48h, Groups 4 & M5

Ridomil Gold MZ 72 (mefenoxam + mancozeb): Broad spectrum fungicide containing 8% metalaxyl and 64% mancozeb effective against both lower and true fungi. REI 48h, Groups 4 & M3

Ridomil Gold Copper (mefenoxam + copper): Broad spectrum fungicide containing 4.8% metalaxyl and 60% copper hydroxide effective against both lower and true fungi. REI 48h, Groups 4 & M1

RootShield AG, WP⁰⁶ (*Trichoderma harzianum* Rifai strain KRL-AG2): Biological treatment. REI 0h, Group NC

RootShield Granules⁰⁶ (*Trichoderma harzianum* Strain T-22): Biological soil treatment. REI 0h, Group NC

RootShield Plus WP, Granules⁰⁶ (*Trichoderma harzianum* Strain T-22 + *T. virens* Strain G-41): Biological fungicide for foliar and soil treatments. REI 0h, Group NC

Roper (DF, DF Rainshield) (mancozeb): A broad spectrum fungicide. REI 24h, Groups M3

Rovral 4 F (iprodione): For *Alternaria*, *Botrytis*, *Rhizoctonia* and *Stemphylium* diseases; sclerotinia diseases; in broccoli, carrots, dry bulb onions, potatoes; white rot of garlic, . REI 24h, Group 2

Scala SC (pyrimethanil): Protective fungicide for bulb, tuberous, and corm vegetables. REI 12h, Group 9

Serenade (ASO⁰⁶, Opti⁰⁶), (*Bacillus subtilis* QST 713): Biological protectant fungicide. REI 4h, Group 44

Sil-MATRIXOG (potassium silicate): Broad spectrum preventive fungicide. REI 4h, Group NC

Sonata⁰⁶ (*Bacillus pumilus* QST 2808): Biological protectant fungicide. REI 4h, Group NC

Sovran 50 WG (kresoxim-methyl): For powdery mildew and gummy stem blight in cucurbits. REI 4h, Group 11

Spirato (fludioxonil): For greenhouse use only on plants and transplants of listed crops. REI 12h, Group 12

Sporan EC (rosemary, clove, and thyme oils): Contact fungicide with broad crop clearance. Group NC

Stargus⁰⁶ (*Bacillus amyloliquefaciens* F727): Broad-spectrum preventive biological fungicide for bacterial spot and blights, botrytis blight, late blight, damping off and root rots, downy mildew (depending upon crops, see label). REI 4h, Group 44

Stratego, Stratego YLD (propiconazole + trifloxystrobin): For diseases of corn. REI 12h, Groups 3 & 11

Subdue MAXX (mefenoxam): For greenhouse-grown transplants for retail sale to consumers. For downy mildew, and soilborne *Pythium* and *Phytophthora* diseases of cole crops, cucurbits, fruiting vegetables, leafy vegetables, and bulb crops. (NOT for transplants grown for commercial field use). REI 0/48h, Group 4

Suffoil-X^{0c} (petroleum oils): Fungicide, insecticide, and miticide labeled for greenhouse transplant production. REI 4h, Group NC

Sulfur 6L (sulfur): For powdery mildew on many crops, rust on asparagus, and some mite pests. REI 24h, Group M6

Super Tin 80 WP (triphenyltin hydroxide): For early blight and late blight of potato (restricted use pesticide). REI 48h, Group 30

Switch 62.5 WG (cyprodinil + fludioxonil): A protective fungicide for use in beans, brassica, carrot, herbs, leafy vegetables, and onions. REI 12h, Groups 9 & 12

Taegro 2 (*B. subtilis* var. *amyloliquefaciens* FZB24): Biological for soilborne diseases in cucurbits, leafy vegetables, and fruiting vegetables. REI 4h, Group 44

Tanos 50 DF (famoxadone + cymoxanil): A penetrant fungicide with locally systemic and curative activities against Downy Mildew and late blight diseases. REI 12h, Groups 11 & 27

Terraclor 400 (PCNB): A fungicide active against soilborne true fungi labeled for greenhouse transplant production. REI 12h, Group 14

Tilt (propiconazole): A protective fungicide for diseases of beans, beets, carrots, celery, onions, and corn. REI 12h, Group 3

Topguard (flutriafol): Cucurbits, fruiting vegetables. REI (varies with crop, see label) Group 3

Topguard EQ (azoxystrobin + flutriafol): Foliar diseases of brassicas, cucurbits, leafy, and fruiting vegetables. REI 12h, Groups 11 & 3

Topsin (4.5FL, M 70 WSB) (thiophanate-methyl): A systemic fungicide with broad spectrum control. REI (varies with crop, see label) Group 1

Torino (cyflufenamid): Powdery mildew of cucurbits and strawberries. REI 4h, Group U6

Triathlon BA (*Bacillus amyloliquefaciens* D747): Microbial fungicide that can be used in the greenhouse. REI 4h, Group 44

Trilogy^{0c} (neem oil): Various fungal diseases. REI 4h, Group NC

Trionic 4SC (triflumazole): Powdery mildew and *Alternaria*. Also labeled for greenhouse use. REI 24h, Group 3

Trivapro (benzovindiflupyr + azoxystrobin + propiconazole): Labeled for corn diseases. REI 12h, Groups 3 & 7 & 11

Ultra Flourish (mefenoxam): A fungicide active against *Pythium*, *Phytophthora*, and downy mildew. REI 48h, Group 4

Vanguard WG (cyprodinil): For management of diseases of onions. REI 12h, Group 9

Vivando (metrofenone): For powdery mildew. REI 12h, Group 50

ZeroTol 2.0^{0c} (hydrogen dioxide): Preventive biocide labeled for greenhouse use. REI 0h (1 h spray), Group NC

Zampro 525SC (ametoctradin + dimethomorph): A fungicide for downy mildew and *Phytophthora* diseases of potatoes and bulb, brassica, cucurbit, fruiting, and leafy vegetables. REI 12h, Groups 40 & 45

Ziram (76DF, Excel) (ziram): For use on tomatoes for anthracnose, septoria leaf spot and early blight. Do not use on cherry tomatoes. REI 48h, Group M3

Zing! (zoxamide): for management of diseases of cucurbits, garlic, onions, potatoes and tomatoes. REI 12h, Groups 22 & M5

Soil Fumigation Outdoors

Soil fumigation is the most drastic measure that growers can perform to eradicate soil-borne pests and is often a method of last resort. Fumigants are general biocides; they are effective against fungi, bacteria, nematodes, soil insects, and weed seeds. They have several serious drawbacks:

- Fumigants kill all organisms, even the beneficial ones that compete with or parasitize plant pathogens. They leave a biological vacuum which can be quickly reinfested with serious plant pathogens.
- Fumigants have a high acute inhalation toxicity and are carcinogenic. They represent a hazard to humans, wildlife, and the environment.
- Fumigants require specialized equipment and procedures to apply properly. They are usually applied by professional crop production services. Soil preparation, temperature, and rate of chemical will determine how effectively pests will be controlled.

Fall is the best time to fumigate. However, it can be very effective in spring with an appropriate post-treatment waiting period. Careful attention should be paid to soil temperature and moisture, as well as time of exposure as indicated on the product label. Plowing below the depth of treatment will mix non-treated and treated soil.

Read the label carefully before using fumigants. All chemical fumigants are restricted use and require a 5-day *Entry Restricted Period* after application.

Telone C-17 (dichloropropene plus chloropicrin) or Telone II (dichloro-propene): 5.0-40 gal/A. Controls certain soil insects, nematodes, and soil-borne fungi. Read and follow the instructions on the label carefully.

InLine (dichloropropene plus chloropicrin): 13.0-20.5 gal/A. Controls certain soil insects, nematodes, and soil-borne fungi. Read and follow the instructions on the label carefully.

Vapam HL, (sodium methyl dithiocarbamate): 50.0-100.0 gal/A. Controls weeds, soil insects, nematodes and soil-borne fungi. Read and follow the instructions on the label carefully.

INSECT MANAGEMENT

A successful insect management program can best be accomplished by combining IPM techniques, such as accurate pest identification, scouting, monitoring, and action thresholds, with biological and preventative control practices and selective insecticide applications if needed.

Use scouting and monitoring techniques to help assess and quantify insect populations over time.

Insecticides should be used only when action thresholds have been exceeded or damaging insect populations are present. Action thresholds help minimize insecticide use and crop damage. Avoid making routine insecticide applications to crops without evidence of insect activity and damage. All insects have natural enemies which, if conserved, can help regulate pest populations. Whenever possible, use selective insecticides that spare beneficial organisms and target the

pest you wish to control. Broad-spectrum insecticides should be used as a last resort. All insecticide applications should be made with ample water and with nozzles directed so that they provide thorough coverage of the plant parts where insects hide. Alternate between insecticide classes or families to help manage insect resistance and extend the life of available products.

Insect Identification

Become familiar with the biology and life-cycle of the major insect pests that attack crops on an annual basis. Understanding some basic insect biology often reveals when the pest is most vulnerable to control measures and helps lead to successful management efforts. Insects usually have either a simple life-cycle, where they grow from egg to nymph to adult, or a slightly more complex cycle, where they mature from egg to larva and then go through metamorphosis in the pupal stage before becoming adults. Insects damage plants either as nymphs/larvae or as adults, or in both immature and adult stages. Learn to recognize the important life-stages of major insect pests, and to recognize the crop injury or damage they produce to help determine when control efforts are needed. You should also be able to identify common beneficial insects and their immature stages (i.e., lady bug larvae) to avoid accidentally targeting natural enemies with insecticides. There are dozens of minor and secondary insect pests that may attack crops on a less frequent basis. Growers should have unknown insects and minor pests identified (see Diagnostics for Plant Problems, page 66) when they are suspected of causing crop damage. Misidentification often leads to the application of an ineffective pesticide and extensive or chronic crop damage. The application of ineffective or unnecessary pesticides can often reduce the populations of beneficial organisms or natural enemies and lead to secondary insect or mite outbreaks. An accurate diagnosis of the problem early on can often prevent years of frustration and needless expense. See the Northeast Vegetable & Strawberry Pest Identification Guide for help with identification.

Scouting and Monitoring

Crops should be inspected or scouted for insects or damage in a systematic fashion, on a regular basis throughout the growing season. For many crops and pests, this may mean walking fields weekly, or even more frequently, especially during critical or vulnerable plant development stages. Crops should be scouted in a systematic fashion by walking in an “M” or “W” pattern as you crisscross the field. Select plants (i.e., 25 or 50) at random and quantify the pest damage or count the individual insects. Record the average number of insects or damage per plant for each field. Scouting crops always saves money in the long run by allowing for early pest detection, by reducing crop damage and by helping to maintain consistent quality. Sometimes scouting duties can be performed by other farm members or by hired consultants.

Monitoring insect populations with various types of traps (black light, pheromone, sticky, baited) can supplement or sometimes substitute for information normally gathered during crop scouting. Insect traps can help you quantify pest pressure that is difficult to see, such as the number of night flying (i.e., corn earworm) moths present. The number of insects captured in traps is often used to time scouting activities, predict future pest levels, or is used in conjunction with action thresholds to time sprays and help avoid crop damage.

Action Thresholds

Action thresholds tell you when to spray to prevent economic damage to the crop. They also help you avoid applying insecticides to crops when insect populations are low or no pests are present. Thresholds can be based on the number of insects found per plant, the amount of injury or damage per plant, or the number of insects captured in a trap. Using action thresholds helps improve insecticide timing and effectiveness, helps minimize the number of applications and associated costs, and helps reduce crop damage and resistance problems. Use action thresholds whenever possible to help you decide if and when a spray is needed. Some insect thresholds are provided in this publication. See your state’s Extension IPM personnel for local action thresholds for specific pests.

Preventative Controls

As mentioned in the introduction to the general Pest Management section, there are many preventative management options, such as cultural, mechanical, physical, genetic and biological controls. These should be used whenever possible to help prevent insect pest problems. Preventative insect control options can be used alone or in combination to provide a complete management program. For example, plant inspections, eliminating weeds in the greenhouse, using screens, avoiding excess nitrogen applications, using plastic mulch and preserving natural enemies can combine to produce a very effective aphid management program. If the distance between fields is great enough, crop rotation (alone) for Colorado potato beetle and cucumber beetles can often keep these tough pests from reaching damaging levels for the entire season. However, if only nearby fields are available, CPB can be effectively controlled by the use of a combination of two or more alternative controls, such as short-distance crop rotation, intervening trap crops or plastic-lined trenches, row covers, organic mulches, flaming, and microbial controls. Many preventative controls are mentioned in crop-specific IPM manuals, individual pest fact sheets and on IPM websites.

Perimeter Trap Cropping utilizes a combination of control measures to concentrate and/or kill pests in the border area of the field. This technique involves planting one or more rows of an attractive plant species so that it completely encircles the less attractive main crop, and intercepts a migrating insect population. Often a chemical or microbial insecticide is used to spot-spray the perimeter trap crop (only), sparing beneficials on the main crop, and substantially reducing insecticide use. Perimeter trap cropping has been shown to be effective at controlling diamondback moth larvae on cabbage, using collards as the trap crop; pepper maggots on bell peppers or eggplant, using hot cherry peppers as the trap crop; and cucumber beetles on summer squash, winter squash, cucumbers, melons, and sometimes pumpkins, using Blue Hubbard squash or another *Cucurbita maxima* variety as the trap crop. This technique may prove useful on related crops and against additional pests in the future.

Insecticides

Follow the label specifications for application rates. **If the rate suggested in this guide does not agree with the current label, follow the label recommendations.** Amounts of pesticides are in lb/A (pounds per acre), oz/A (ounces per acre) or pt/A (pints per acre) of commercial formulation, not a.i. (active

ingredient), unless otherwise stated. The percentage by weight or concentration of a.i. varies with different brands of pesticides. The label gives pounds of a.i. in each commercial preparation. For example, Lorsban 4E has 4 lb active ingredient/gallon of formulated material.

The amount of insecticide recommended per acre should not be changed when varying gallonage of water per acre. Make sure a pesticide is labeled for concentrate application before using a low volume sprayer, air or mist sprayer, aircraft or other concentrate application equipment.

Seed Treatments

Insecticide seed treatments may help protect your crop from soil insects and other early-season pests. Some of the seed treatments listed under various crops must be applied by a professionally licensed seed coating applicator. In some cases, the use or purchase of treated seed may be economical as it may result in a substantial reduction in pesticide use and increase the plant stand and yield in the field.

Resistance Management

Adult pests that survive an environmental hardship, such as the application of an insecticide, are likely to pass the trait that enabled them to survive on to their offspring. Repeat applications with the same type of pesticide will eventually remove almost all the susceptible individuals from a pest population and leave only those with the resistant gene. Because insects and mites go through generations quickly, resistance to an overused pesticide can develop in as little as three years.

To preserve the useful life of a pesticide, it is necessary to practice resistance management. The most effective way to extend the useful life of an effective product is to use it on a single pest generation only, and then on the next generation use a second pesticide with a different method of killing the pest (mode of action). On some pests particularly prone to developing resistance (i.e., Colorado potato beetle) it is best to use a product with a particular mode of action on one generation every second year only. To help select pesticides with a different mode of action, see chemical resistance groupings in Table 27, page 108. These resistance group numbers, or IRAC codes, were developed by the Insecticide Resistance Action Committee (IRAC). Products with the same code (number and letter) indicate products with a common mode of action. For multiple applications to the same crop, select products from different resistance groups.

Once a pest develops resistance to a group of pesticides with a particular mode of action, a higher rate of a similar chemical from the same group usually will not control the insect.

NOTE: There is no cross-resistance between insecticides, herbicides and fungicides. For example, there is no problem when using material from the herbicide group 1 and an insecticide or fungicide from group 1.

There are many other techniques that can help delay the onset of resistance. Most resistance management techniques help minimize the use of pesticides so that a lower proportion of each pest generation is exposed to the toxin.

- Integrate chemical control with effective cultural, mechanical, physical, and genetic management options.
- Use biological/microbial control agents or other selective pesticides to preserve natural enemies and help minimize the number of repeat applications.

- Scout, monitor and use action thresholds to ensure that applications are necessary.
- Good spray coverage helps do the job right the first time and avoids unnecessary repeat applications: use the proper size nozzles and the correct angle or orientation and an adequate amount of water per acre.
- Time the application so that the most vulnerable insect life stage is exposed to the spray.
- Use spot sprays, perimeter trap crop treatments, refuge plantings, and other methods that prevent the entire field or population from being treated to help preserve susceptible individuals.

Toxicity Rating of Insecticides

Insecticides vary greatly in their toxicity to humans and the environment. The toxicity of the insecticide is usually stated in the precaution on the label. For example, a skull and crossbones figure and the signal word “Danger” are always found on the label of highly toxic (Toxicity Class I) materials. Those of medium toxicity (Toxicity Class II) carry the signal word “Warning.” The least toxic materials (Toxicity Class III) have the signal word “Caution.” The toxicity of a pesticide is expressed in terms of oral and dermal LD₅₀. LD₅₀ is the dosage of poison that kills 50% of test animals (usually rats or rabbits) with a single application of the pure pesticide for a given weight of the animal (mg/kg of body weight). The lower the LD₅₀ value, the more toxic the material. Oral LD₅₀ is the measure of the toxicity of pure pesticide when administered internally to test animals. Dermal LD₅₀ is the measure of the toxicity of pure pesticide applied to the skin of test animals. Generally, an oral exposure is more toxic than a dermal one.

Protecting Honeybees and Native Pollinators

Honeybees and native pollinators visit vegetable crops during flowering and pollen shed. In crops such as cucurbits, their activity is crucial to the success of the crop. In other crops such as sweet corn or potato, bees are among many beneficial insects that seek out pollen or nectar resources as a food source, but crop yield does not depend upon their activity. Populations of honeybees and native pollinators have declined worldwide in recent years. Many factors have contributed to their decline. Pesticides applied to crops is one of these factors.

Pesticides applied to protect vegetable crops can affect pollinators through multiple routes of exposure: direct contact with sprays, contact with treated surfaces, pesticide-contaminated dust or pollen particles that are collected or adhere to the body of the insect (and may be taken back to hive), and ingestion of pesticide-contaminated nectar. Decisions made by the farmer make a difference in the exposure of bees and other beneficials to toxic levels of pesticides. While pesticides applied to crops are only one among many factors that threaten pollinators, this is one factor that growers can do something about. Taking precautions to minimize pesticide poisoning of pollinators in all crops is an important responsibility of all pesticide applicators.

Steps that can reduce pesticide exposure of pollinators:

Timing. Avoid applications when crop or weeds are in bloom. In crops that bloom over long periods, make applications late in the day or at night when pollinators are not foraging, and so that there is sufficient drying time before foraging begins. Control weeds.

Formulation. Wettable powders, dusts and microencapsulated products have a greater toxic hazard than emulsifiable concentrates (or other liquid formulation with active ingredient in solution). Products that do not have acute toxicity but could cause injury to immature bees if carried back to the hive should not be applied in particulate form; this includes insect growth regulators.

Drying time before exposure. Some products are highly toxic when wet, but much less so after the pesticide is dried. Spinosyns have this characteristic. Apply when there will be adequate drying time (usually 2-3 hours, depending on weather conditions and crop canopy) before pollinator activity.

Drift. Avoid drift on non-target areas near the field where blooming plants may be located. Windspeed and application equipment both influence drift.

Mode of application. Soil and seed applications reduce exposure compared to foliar applications, unless plant uptake of the active ingredient produces residues in pollen or nectar. In the case of neonicotinoids, there is evidence that foraging bees may receive sublethal doses in pollen and nectar when cucurbit crops were treated with a systemic at early growth stages. This effect appears to be reduced by using lower rates and applying as early as possible, but may not be entirely eliminated by these methods. A sublethal dose may make bees more vulnerable to other stressors, or may combine with doses from contact with other treated plant material.

Acute toxicity. Avoid applying insecticides rated as High or Medium directly to bees that are actively foraging on blooming crop or weeds. See Table 27 (page 108) for information on insecticide active ingredients and toxicity. EPA registration includes an acute, single-dose laboratory study designed to determine the quantity of pesticide that will cause 50% mortality (LD₅₀) in a test population of bees.

Read the label for bee hazard rating. If a pesticide is used outdoors as a foliar application, and is toxic to pollinating insects, a “Bee Hazard” warning has generally been required to be included in the Environmental Hazards section of the label. The EPA bee toxicity groupings and label statements are as follows:

- **High (H)** Bee acute toxicity rating: LD₅₀ = 2 micrograms/bee or less. The label has the following statement: “This product is highly toxic to bees and other pollinating insects exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees or other pollinating insects are visiting the treatment area.” If the residues phrase is not present, this indicates that the pesticide does not show extended residual toxicity.
- **Moderate (M)** Product contains any active ingredient(s) with acute LD₅₀ of greater than 2 micrograms/bee but less than 11 micrograms/bee. Statement: “This product is

moderately toxic to bees and other pollinating insects exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product if bees or other pollinating insects are visiting the treatment area.”

- **Low (L)** All others. No bee or pollinating insect caution required.

In this guide, Table 26 (Information about Insecticides and Miticides) gives the bee toxicity rating (H, M or L) for each active ingredient. In the Insect Management section for each crop, the bee toxicity rating is given for each insecticide listed.

Insecticides Alphabetical Listing by Trade Name

The symbol * indicates a Federally restricted-use pesticide

The symbol ⁰⁶ indicates a pesticide that has been listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production.

Some products are described in detail as examples for a given active ingredient (AI). For more information on other products with the same AI, refer to the example. Always refer to the specific product label before applying any product.

At the time of writing, all products listed were registered in at least one New England state. Check registration status in your state before using any product.

Abacus* (abamectin): See Agri-Mek for more information.

Abamex* (abamectin): See Agri-Mek for more information.

Acephate (acephate): See Orthene for more information.

Acramite (bifenazate): A selective miticide which acts on contact as a nerve toxin with knockdown activity and long residual. Registered as a foliar spray for control of mites on cucurbits, eggplant, okra, peppers, field-grown tomatoes (for greenhouse tomatoes, see bifenazate product, Floramite), succulent beans and peas, and herbs. Relatively safe on beneficials. (Group un, REI 12h)

Actara (thiamethoxam): A systemic neonicotinoid with translaminar activity, registered for use as a foliar spray for control of aphids, flea beetles, leafhoppers, whiteflies, and other pests on brassicas, cucurbits, fruiting vegetables, globe artichoke, leafy vegetables, mint, and root and tuberous vegetables. Do not use in greenhouses or on plants grown for use as transplants. Highly toxic to bees. (Group 4A, REI 12h)

Admire (imidacloprid): A systemic neonicotinoid, registered for use in soil, seed piece, and foliar applications. Labeled for use on cucurbits, herbs, brassicas, legumes, roots, bulbs, tubers, corms, globe artichoke, and fruiting and leafy vegetables for control of aphids, flea beetles, leafhoppers, whiteflies, thrips and Colorado potato beetle. Also labeled for use in greenhouses on mature cucumber and tomato plants to control aphids and whiteflies. Do not apply to non-soil media or in hydroponic systems. Specific labeled application methods vary by crop. Highly toxic to bees. (Group 4A, REI 12h)

Advise (imidacloprid): See Admire for more information.

Agri-Mek* (abamectin): A locally systemic, selective chloride channel activator insecticide and miticide, derived from a metabolite of a soil bacterium, *Streptomyces avermitilis*. Registered for use as a foliar spray with translaminar activity to control spider mites on celeriac and sweet corn, thrips and leafminers on onions (bulb & green), and mites and leaf miners on cucurbits, dry beans, fruiting vegetables, herbs, tubers and corms, and non-brassica leafy greens. Also controls Colorado potato beetle and tomato and potato psyllid on fruiting vegetables and

potatoes. Labeled for use on commercially produced greenhouse tomato for leafminer, mites, thrips, tomato psyllid, and tomato pinworm. Highly toxic to bees. (Group 6, REI 12h)

Akari (fenpyroximate): See Portal for more information.

Alias (imidacloprid): See Admire for more information.

Amazin Plus⁰⁶ (azadirachtin): See Azatin for more information.

Ambush* (permethrin): See Pounce for more information.

AmTide Imidacloprid (imidacloprid): See Admire for more information.

Arctic* (permethrin): See Pounce for more information.

Asana* (esfenvalerate): A broad-spectrum, pyrethroid insecticide that works by contact and ingestion. Labeled for foliar applications on artichoke, beans, brassicas, carrots, cucurbits, fruiting vegetables, roots, sweet corn and potatoes to control a wide variety of pests. Extremely toxic to fish and aquatic invertebrates and highly toxic to bees. (Group 3, REI 12h)

Assail (acetamiprid): A selective neonicotinoid, with translaminar activity, that controls sucking and chewing insects through contact and ingestion. Registered to control aphids, whitefly and other pests on asparagus, leafy vegetables, cole crops, fruiting vegetables, cucurbits, sweet corn, and succulent peas and beans. Also labeled for control of thrips on bulb vegetables, as well as aphids, Colorado potato beetle, flea beetle and other pests on tuberous and corm vegetables. (Group 4A, REI 12h)

Athena* (abamectin + bifenthrin): A mixture of a broad-spectrum pyrethroid and bacterium-derived chloride channel activator. See Agri-Mek and Brigade for more information on active ingredients in this product.

Avaunt (indoxacarb): A sodium channel blocker with translaminar activity that causes paralysis and death after being ingested on plant tissue. Labeled for use as a foliar spray on brassicas, cucurbits, fruiting vegetables, beets, leafy greens, leafy petioles, mint, and tubers and corms to control caterpillars. Also registered to control European corn borer and fall armyworm in whorl and be used in irrigation systems except for application to potatoes and sweet corn. Relatively safe for beneficials, but toxic to bees exposed to direct treatment. (Group 22, REI 12h)

Aza-Direct⁰⁶ (azadirachtin): See Azatin for more information.

AzaGuard⁰⁶ (azadirachtin): See Azatin for more information.

Azatin⁰⁶ (azadirachtin): A natural insect growth regulator extracted from the seeds of the neem tree, works by contact or ingestion against immature insect stages and has anti-feedant properties. Has some systemic activity and can be taken up by plant roots; may be used as a transplant drench. Registered for use as a foliar spray in field and greenhouse on all vegetable and vegetable transplants and herbs to control multiple pests. Short residual. Note: Azatin O is OMRI certified, but Azatin XL is not. (Group un, REI 4h)

Azatrol⁰⁶ (azadirachtin): See Azatin for more information.

Azera⁰⁶ (azadirachtin + pyrethrin): See Azatin and Pyganic for more information.

Aztec* (beta-cyfluthrin + tebuprimphos): A mix of pyrethroid and organophosphate chemistries registered for soil applications in sweet corn and popcorn for control of corn rootworms, cutworms, wireworms, seedcorn maggot, seedcorn beetle, and white grubs. (Group 1B, REI 48h)

Baythroid* (beta-cyfluthrin): A broad-spectrum, pyrethroid insecticide that works by contact or ingestion, labeled for foliar applications on brassicas, cucurbits, fruiting vegetables, leafy greens, dry beans, potatoes and other tubers and corms, carrots, radishes, and sweet corn for contact control of caterpillars, flea beetles, stink bugs, and other pests. Extremely toxic to fish and aquatic invertebrates and highly toxic to bees. (Group 3, REI 12h)

Belay (clothianidin): A neonicotinoid with long residual control, registered for use in foliar and soil applications on brassicas, cucurbits, and fruiting and leafy vegetables. Becomes systemic when applied to soil, and has translaminar activity when applied to foliage. Labeled to control aphids, flea beetles, stink bugs, leafhoppers, cucumber beetles, Colorado potato beetle, and other pests. Also labeled for use on tuberous and corm vegetables in foliar, seed piece and soil applications to control aphids, Colorado potato beetle, wireworms, white grubs, and other pests. Highly toxic to bees. (Group 4A, REI 12h)

Beleaf (flonicamid): A pyridinecarboxamide with translaminar activity that works by contact and ingestion. Feeding stops rapidly and mortality will follow. Labeled for use on brassicas, cucurbits, fruiting vegetables, leafy greens, tubers and corms, root vegetables, greenhouse cucumbers and tomatoes and mint for selective control of aphids, plant bugs and greenhouse whitefly. (Group 9C, REI 12h)

Belt (flubendiamide): Note: All flubendiamide registrations were canceled by the EPA in 2016. Growers may use up existing stock. A diamide, active by insect larval ingestion, leading to a rapid cessation of feeding followed by death. Labeled for use as a foliar spray on brassicas and turnip greens, corn, cucurbits, fruiting vegetables, and legumes to control caterpillars. Not labeled for use in enclosed structures, such as greenhouses. (Group 28, REI 12h)

Besiege* (chlorantraniliprole + lambda-cyhalothrin): See Coragen and Warrior for more information.

Bifenture* (bifenthrin): See Brigade for more information.

Blackhawk (spinosad): See Entrust for more information.

Bolton* (chlorpyrifos+ gamma-cyhalothrin): See Lorsban and Declare for more information.

Bonide Garden Dust (sulfur): See Microthiol Dispers

Botanigard (*Beauveria bassiana*): See Mycotrol ESO for more information. Not approved for organic production. Notes: ES formulation may be phytotoxic to tomatoes. Maxx formulation contains pyrethrins.

Brigade* (bifenthrin): A broad-spectrum, pyrethroid insecticide and miticide. Labeled for use as a foliar spray on a wide variety of crops to control aphids, flea beetles, leafhoppers, stink bugs, caterpillars and several other pests. Extremely toxic to fish and aquatic invertebrates and highly toxic to bees. Prohibited in areas where application may result in exposure to endangered species. (Group 3A, REI 12h)

Brigadier* (bifenthrin + imidacloprid): See Brigade and Admire for more information.

Captiva (capsicum oleoresin extract + garlic oil): A repellent and insecticide made from concentrated plant extracts. Works by contact. Has anti-feedant, anti-egg laying, and irritant activity, and weakens cuticles of immature stages of some insect and mite pests. Registered for foliar applications in field and greenhouse on all food crops including greenhouse vegetable and transplant production to repel or suppress soft-bodied pests. (No resistance classification, REI 4h)

Capture* (bifenthrin): A broad-spectrum, pyrethroid insecticide and miticide, labeled for soil applications. Capture LFR can be mixed

directly with liquid fertilizer or with water. Registered for use on a wide variety of crops to control wireworm, grubs, root maggot, cutworm, flea beetle larvae, and other soil dwelling pests. Extremely toxic to fish and aquatic invertebrates and highly toxic to bees. Prohibited in areas where application may result in exposure to endangered species. (Group 3A, REI 12h)

Carbaryl (carbaryl): See Sevin for more information.

Chlorpyrifos* (chlorpyrifos): See Lorsban for more information.

Clinch Ant Bait* (abamectin): A selective chloride channel activator insecticide that kills ants by ingestion, and acts to cease viable egg production. Registered as a soil treatment in various crops to control fire ants. Long residual. (Group 6, REI 12h)

Closer (sulfoxaflor): See Transform for more information. Note: After being cancelled in 2015, sulfoxaflor registrations have been reinstated by the EPA under limited-use restrictions.

Cobalt* (chlorpyrifos + gamma-cyhalothrin): Labeled for Brussels sprouts and sweet corn. See Lorsban and Declare for more information.

Cobalt Advanced* (chlorpyrifos + lambda-cyhalothrin): See Lorsban and Warrior for more information.

Confirm (tebufenozide): A selective insect growth regulator that induces a premature lethal molt within hours of ingestion. Labeled for use on brassicas, leafy vegetables, turnips, and fruiting vegetables and mint to control caterpillars. Not disruptive to beneficials and bees. (Group 18, REI 4h)

Consero* (spinosad + gamma-cyhalothrin): Labeled for corn and legumes. See Entrust and Declare for more information.

Coragen (chlorantraniliprole): A diamide that has contact activity, but is most effective through ingestion of treated plant material. Insects rapidly stop feeding, become paralyzed and typically die within 1-3 days. Becomes systemic when applied to soil. Labeled for use as a foliar spray on artichoke, asparagus, bulb vegetables, corn, herbs, legumes, and roots and tubers to control caterpillars; and potatoes to control caterpillars and Colorado potato beetle. Also labeled as a foliar, drip irrigation, and soil treatment on brassicas, cucurbits, and fruiting and leafy vegetables to control caterpillars, leafminer and whitefly larvae, and Colorado potato beetle. Also labeled as a transplant water treatment for suppression of cabbage root maggot in leafy brassicas. Effective against difficult to control caterpillars such as beet and fall armyworm. Relatively safe for beneficials and non-target organisms. (Group 28, REI 4h)

CoStar (*Bacillus thuringiensis* subsp. *kurstaki*): See Dipel for more information.

Couraze (imidacloprid): See Admire for more information.

Cruiser (thiamethoxam): A systemic neonicotinoid commercial seed treatment that is taken up by the seedling plant and controls chewing and sucking insects through contact and ingestion. Labeled for use on cucurbits, legumes and potatoes to control aphids, leafminers, wireworms and several other pests, including Mexican bean leaf beetle and thrips on legumes and Colorado potato beetle on potatoes. Highly toxic to bees. (Group 4A, REI 12h)

Damoil (mineral oil): See Suffoil-X for more information.

Danitol* (fenpropathrin): A pyrethroid insecticide-miticicide with contact activity. Labeled for use on cucurbits, fruiting vegetables, brassicas and peas to control a wide variety of pests including aphids, caterpillars, flea beetles, spotted wing drosophila, Colorado potato beetle, and stink bugs. Extremely toxic to fish and aquatic organisms, and highly toxic to bees. (Group 3A, REI 24h)

Deadline M-Ps (metaldehyde): A toxic bait for slugs and snails. Labeled for use as a soil surface treatment for most vegetable crops. Not for direct application to or contamination of edible portions of the plant; to be applied as a band treatment between rows after formation of edible parts. Long-lasting; resistant to rain and watering. (No resistance classification, REI 12h)

Declare* (gamma-cyhalothrin): A microencapsulated broad-spectrum pyrethroid that acts on contact and via ingestion. Registered for use on brassicas, sweet corn, popcorn, cucurbits, fruiting vegetables, legumes, lettuce, onion, garlic, tuberous and corm vegetables to control a wide variety of pests. Highly toxic to bees and extremely toxic to aquatic organisms. (Group 3A, REI 24h)

Defcon* (beta-cyfluthrin + tebufirimfos): For control of soil insects in corn. See Baythroid and Aztec for more information.

Deliver⁰⁶ (*Bacillus thuringiensis* subsp. *kurstaki*): See Dipel for more information.

Delta Gold* (deltamethrin): A broad-spectrum, pyrethroid insecticide. Labeled for use on corn, cucurbits, bulb, fruiting, root, tuberous and corm vegetables, and globe artichoke to control a wide variety of pests. Extremely toxic to fish and aquatic invertebrates, and highly toxic to bees. (Group 3A, REI 12h)

DES-X⁰⁶ (insecticidal soap): See M-Pede for more information.

Diazinon* (diazinon): An organophosphate with contact activity, labeled for use as a soil spray to be broadcast before planting and incorporated into the soil. Labeled for use on succulent legumes, tomatoes, and specific brassicas, melons, roots, and leafy greens to control cutworms, wireworms, and on some crops mole crickets and/or root maggots. Not to be used in greenhouses. Highly toxic to bees. (Group 1B, REI 2 to 4 days depending on crop)

Dimate (dimethoate): See Dimethoate for more information.

Dimethoate (dimethoate): A broad-spectrum organophosphate with systemic and contact activity against piercing, sucking, and chewing insects and mites. Labeled for use on asparagus, beans, some brassicas, leafy greens, melons (except watermelons), celery, fruiting crops, succulent beans. Useful for control of pepper maggot in peppers. Not to be used in greenhouses. Highly toxic to bees. (Group 1B, REI 48h)

Dimilin* (diflubenzuron): A selective insect growth regulator that disrupts the molting process of insect larvae. Labeled for use on peppers to control armyworms and pepper weevils. Not disruptive to bees or other beneficial insects. (Group 15, REI 12h)

Dipel⁰⁶ (*Bacillus thuringiensis* subsp. *kurstaki*): A bacterium-derived insecticide that works by ingestion. Labeled for use on root, tuber, bulb, leafy green, brassica, legume, fruiting and cucurbit vegetables to control caterpillars. Safe for bees and beneficial insects. Note: Dipel ES is not OMRI listed, Dipel DF is. (Group 11A, REI 4h)

Discipline* (bifenthrin): See Brigade for more information.

Distance IGR (pyriproxyfen): An insect growth regulator that works by suppressing the development of the embryo within the egg and inhibiting metamorphosis of nymphs, larvae, and pupae into adults. Works by contact and ingestion. Labeled for use as a foliar spray with translaminar activity when used on indoor-grown fruiting vegetables to control greenhouse, silverleaf, and sweet potato whitefly, as well as fungus gnats and shore flies when applied as a soil drench. (Group 7D, REI 12h)

Durivo (chlorantraniliprole + thiamethoxam): See Coragen and Actara for more information.

Ecotrol Plus⁰⁶ (rosemary oil + peppermint oil + geraniol): A broad-spectrum, plant-based granular insecticide that works on contact.

Labeled for foliar application to a variety of crops for control of aphids, beetles, plant bugs, whiteflies, mites, thrips, and early stages of caterpillars. This product is exempt from EPA pesticide registration requirements.

Ecotrol G2^{0G} (rosemary oil + peppermint oil): A broad-spectrum, plant-based granular insecticide, formulated from plant oils on ground corn cob. Incorporate as a band or with seeds at or after planting. Labeled for use on a variety of crops for control of wireworms, cutworms, root maggots, and symphylans. This product is exempt from EPA pesticide registration requirements.

Ecozin^{0G} (azadirachtin): See Azatin for more information.

Empower* (bifenthrin): See Brigade (for foliar applications) or Capture (for soil applications) for more information. Granular formulations may not be applied in coastal counties.

Endigo* (lambda-cyhalothrin + thiomethoxam): See Warrior and Actara for more information.

Entrust^{0G} (spinosad): A nerve and stomach poison derived from the soil bacterium, *Saccharopolyspora spinosa*. Registered for use as a foliar spray with some translaminar activity on asparagus, brassicas, bulb vegetables, corn, cucurbits, fruiting vegetables, herbs, leafy greens, legumes, roots, and tubers to control lepidopteran larvae, Colorado potato beetle, leafminers, thrips and other pests. Helps conserve beneficial predators, but may be toxic to some parasites of insect pests. Toxic to bees for three hours following treatment. (Group 5, REI 4h)

Esteem (pyriproxyfen): An insect growth regulator that works by suppressing the development of the embryo within the egg and inhibiting metamorphosis of nymphs, larvae, and pupae into adults. Does not control adult insects. Labeled for use as a foliar spray with translaminar activity on dry bulb onions to control onion and Western flower thrips and on legumes to control silverleaf and sweet potato whitefly. Not for use in irrigation systems. (Group 7D, REI 12h)

Evergreen (pyrethrins + piperonyl butoxide): See Pyganic and Pyronyl Crop Spray for more information.

Exirel (cyantraniliprole): A diamide that has some contact activity, but is most effective through ingestion. Labeled for use as a foliar spray on brassica, bulb, cucurbit, fruiting, and leafy vegetables, as well as greenhouse-grown eggplant, pepper, and tomato to control sucking and chewing insects including lepidopteran larvae, aphids, flea beetle, leafminers, thrips, and whitefly. Highly toxic to bees. (Group 28, REI 12h)

Fanfare* (bifenthrin): See Brigade for more information.

Fastac* (alpha-cypermethrin): A broad-spectrum pyrethroid insecticide. Labeled for foliar applications on brassicas, sweet corn, cucurbits, fruiting vegetables, leafy vegetables, and legumes to control a wide variety of pests. Extremely toxic to fish and aquatic invertebrates and highly toxic to bees. (Group 3A, REI 12h)

Floramite (bifenazate): A selective contact carbazate miticide with knockdown activity and long residual. Labeled for use on greenhouse tomatoes (for field tomatoes, see bifenazate product, Acramite) to control mites. Relatively safe on beneficials. (Group un, REI 12h)

Force* (tefluthrin): A pyrethroid that works by ingestion and contact. Labeled for use in band and in-furrow soil applications at planting on sweet corn and popcorn to control wireworms, seedcorn maggots, white grubs and other soil insect pests. (Group 3A, REI 48h)

Fulfill (pymetrozine): A selective homopteran feeding blocker that works primarily by ingestion, but has some contact activity. Labeled for use as a foliar spray on potatoes and other tuberous roots and corms,

asparagus, brassicas, cucurbits, and fruiting and leafy vegetables to control aphids. Translaminar, long residual. Low toxicity to beneficials, including bees, but do not apply to bees that are actively foraging. (Group 9B, REI 12h)

Fyfanon (malathion): See Malathion for more information.

GF-120 Naturalyte Fruit Fly Bait^{0G} (spinosad): An insecticidal bait labeled for use as a foliar and soil spray on vegetable and food crops to control tephritid fruit flies. Highly toxic to bees if directly applied. (Group 5, REI 4h)

Gnatrol^{0G} (*Bacillus thuringiensis* subsp. *israelensis*): A bacterium-derived larvicide labeled for use as a soil drench on vegetable plants including brassicas, tomatoes, leafy vegetables, cucumbers, peppers, and eggplants to control fungus gnat larvae. (Group 11, REI 4h)

Golden Pest Spray Oil^{0G} (soybean oil): A soybean-derived horticultural oil that works as a contact insecticide, as well as a feeding and oviposition deterrent. Labeled for use in sweet corn for control of earworm root worms and fall armyworm. Also labeled for use on a range of vegetable crops to control other soft-bodied insects. (No resistance classification, REI 4h)

Grandevo^{0G} (*Chromobacterium subsugae* strain PRAA4-1 & spent fermentation media): A selective biological insecticide/miticide that works as a stomach poison upon ingestion. Labeled for use as a foliar spray or in chemigation for control of certain caterpillars, foliage-feeding beetles, aphids, whiteflies, mites, leafhoppers and thrips on many vegetable crops. (No resistance classification, REI 4h)

Grizzly* (lambda-cyhalothrin): See Warrior for more information.

Harvanta (cyclaniliprole): A broad-spectrum diamide. Labeled for use in leafy vegetables, heading brassicas and leafy and fruiting vegetables for caterpillars, flea beetles, thrips, stink bugs, and aphids (Group 28, REI 4h)

Hatchet* (chlorpyrifos): See Lorsban for more information.

Hero* (bifenthrin + zeta-cypermethrin): See Brigade and Mustang for more information.

Holster* (zeta-cypermethrin): See Mustang for more information.

Imidan (phosmet): A broad-spectrum organophosphate labeled for use on potato and sweet potato to control Colorado potato beetle, European corn borer, flea beetle, potato leafhopper, and other pests. Potatoes and sweet potatoes must be harvested mechanically. Highly toxic to bees. (Group 1B, REI 5 days)

Intrepid (methoxyfenozide): A selective diacylhydrazine insect growth regulator that works by ingestion. Labeled for use on leafy brassicas, other leafy greens, cucurbits, fruiting vegetables, root vegetables, sweet potato, globe artichoke, green onions, legumes, popcorn, and herbs. Controls caterpillars by causing a premature and incomplete lethal molt. Safe for bees and other beneficial insects. (Group 18, REI 4h)

Javelin^{0G} (*Bacillus thuringiensis* subsp. *kurstaki*): See Dipel for more information.

JMS Stylet Oil^{0G} (paraffinic oil): See Suffoil-X for more information. Note: Organic JMS Stylet Oil is OMRI listed; JMS Stylet Oil is not.

Kanemite (acequinocyl): A selective miticide with knockdown and residual activity. Labeled for use as a foliar spray on fruiting vegetables, edible-podded beans, and edamame to control two-spotted spider mite, and on cucurbits, succulent shelled beans, and okra to control two-spotted spider mites and broad mites. Shows efficacy on all mite life stages. Relatively harmless to most predaceous mites and beneficial insects, (Group 20B, REI 12h)

Knack (pyriproxyfen): An insect growth regulator that works by contact on immature stages. No activity against adult insects. Labeled for use as a foliar spray with translaminar activity on brassicas, cucurbits, succulent and dry legumes, and roots and tubers to control various whitefly species. Also labeled for use on tomatoes to control whiteflies, armyworms, tomato pinworm, thrips and other pests; for other fruiting vegetables to control whiteflies, cabbage looper, green peach aphids, and tobacco hornworm; and for bulb vegetables to control onion thrips. (Group 7C, REI 12h)

Kontos Greenhouse and Nursery (spirotetramat): For use in greenhouses on vegetable transplants for resale only. See Movento for more information.

Lambda-Cy* (lambda-cyhalothrin): See Warrior for more information.

Lambda-T2* (lambda-cyhalothrin): See Warrior for more information.

Lannate* (methomyl): A broad-spectrum carbamate insecticide with translaminar activity. Works on contact, and short-term via ingestion of treated foliage, on all pest life stages. Registered as a foliar spray on a variety of crops for control of aphids, caterpillars, and beetles, including brown marmorated stinkbug. Effective on melon aphids. Other aphids and some caterpillars, such as diamondback moth and cabbage loopers, tend to be resistant. Short residual. Highly toxic to bees. (Group 1A, REI 48h)

Leverage* (imidacloprid + beta-cyfluthrin): See Admire and Baythroid for more information.

Lorsban* (chlorpyrifos): An organophosphate that acts as a nerve toxin. Registered as a soil treatment for brassicas, corn, dry bulb onions, legumes, and sweet potato for control of soil pests including cutworms, root maggots and wireworms. Also registered as a foliar spray on brassicas, corn and soybeans for a range of pest species. Long residual. Highly toxic to bees. (Group 1B, REI 24h, 3 days for cauliflower)

Macho (imidacloprid): See Admire for more information.

Majestene OR (Heat-killed *Burkholderia* spp.): See Venerate for more information. Also has a 2(ee) use as a seed treatment, in-furrow at planting, or as a soil drench for the suppression of wireworms, white grubs, as well as root knot, dagger, cyst, stunt, and lesion nematodes attacking potato and sweet potato. (Group un, REI 4h)

Malathion (malathion): An organophosphate insecticide that acts by contact as a nerve toxin. Registered as a foliar spray on a variety of vegetable crops to control a wide range of insect pests. Highly toxic to bees. (Group 1B, REI 12h to 2 days, depending on crop)

Mallet (imidacloprid): Labeled for use inside greenhouses through irrigation or drench application or as a foliar spray for vegetable transplants and nursery stock for resale only. See Admire for more information. Refer to specific product label before applying.

Marathon (imidacloprid): Labeled for use inside greenhouses for vegetable transplants and nursery stock for resale only. See Admire for more information.

Match-up* (bifenthrin + chlorpyrifos): See Brigade and Lorsban for more information.

Met52 (*Metarhizium anisopliae* Strain F52): Composed of spores of a naturally occurring insect pathogenic fungus. Spores attach to the insect and hyphae penetrate the exoskeleton, growing inside and causing death, usually taking 3-7 days from exposure, depending on temperature. Labeled for use as a foliar spray or soil drench on field and greenhouse onions to control thrips, and on field and greenhouse cucurbits, celery, lettuce, spinach, peppers, and tomatoes to control

thrips, whiteflies, and mites. Persistence will generally be higher when incorporated into soil, but may be effective for a few months even in foliar applications. The EPA reports that *M. anisopliae* strain F52 is not harmful to earthworms or to such beneficial insects as lady beetles, green lacewings, parasitic wasps, honey bee larvae, and honey bee adults. (No resistance classification, REI 0h when mechanically soil-incorporated, 4h otherwise)

Microfine sulfur⁰⁶ (sulfur): See Microthiol Dispers for more information.

Microthiol Dispers^{0G} (sulfur): Micronized wettable sulfur for use on a variety of crops to control mites. (Group M2 fungicide, no insect resistance classification, REI 24h)

Midash Forte (imidacloprid): See Admire for more information.

Mite-E-Oil (mineral oil): See Suffoil-X for more information.

Mocap* (EC) (ethoprop): An organophosphate nematocide-insecticide that works as a nerve toxin. Labeled for soil applications on mint, potatoes, and sweet potatoes to control various soil pests. Extremely toxic to birds. (Group 1B, REI 48h)

Molt-X⁰⁶ (azadirachtin): See Azatin for more information.

Montana (imidacloprid): See Admire for more information.

Movento (spirotetramat): A tetrionic acid derivative insecticide that works primarily by ingestion against immature pest stages. Fertility of adult stages may also be reduced. It is taken up by leaves and translocated to become fully systemic. Registered as a foliar spray on several vegetable crops to control thrips, aphids, swede midge and other pests. Potentially toxic to bee larvae through residues in pollen and nectar, but not to adult honeybees. Not for use in greenhouses. (Group 23, REI 24h)

M-Pede⁰⁶ (potassium salts of fatty acids): An insecticidal soap that works by contact as an insecticide, miticide, and fungicide. Registered for use as a foliar spray for most vegetable and herb crops for control of a variety of insect pests; also active against powdery mildew. Must be applied directly to and thoroughly cover target insects. Avoid treatment when plants are stressed. Can be phytotoxic to some crops; test on small plot. May harm beneficials. (No resistance classification, REI 12h)

Mustang* (zeta-cypermethrin): A pyrethroid insecticide that works by contact as a nerve toxin. Registered for use as a foliar spray on globe artichoke, brassicas, bulbs, sweet corn, cucurbits, fruiting vegetables, leafy greens, legumes, roots, and tubers for control of a wide variety of insect pests. Highly toxic to bees. Extremely toxic to aquatic organisms. (Group 3A, REI 12h)

Mycotrol ESO (*Beauveria bassiana*): A fungus that kills adults or larvae by penetrating the cuticle and growing inside the insect. Target pest must contact pesticide directly or be on treated foliage. Registered for use in field and greenhouse on most vegetable crops for control of grasshoppers, aphids, whiteflies, thrips, leafhopper, caterpillars and leaf-feeding beetles, including Colorado potato beetle. Approved for organic production by the Washington State Department of Agriculture. (No resistance classification, REI 4h)

Nealta Miticide (cyflumetofen): A beta-ketonitrile contact miticide labeled for use on tomatoes to control tertanychid mites only. (Group 25, REI 12h)

Neemix⁰⁶ (azadirachtin): See Azatin for more information.

Nudrin* (methomyl): See Lannate for more information.

Nufarm Abamectin* (abamectin): See Agri-Mek for more information.

Nufos* (chlorpyrifos): See Lorsban for more information.

Nuprid (imidacloprid): See Admire for more information.

Oberon (spiromesifen): A selective tetrionic acid derivative insecticide and miticide with translaminar activity. Works on contact and by ingestion to kill juvenile stages of target pests, particularly whitefly pupae. Registered as a foliar spray on sweet corn, cucurbits, fruiting vegetables, leafy greens, brassicas, and tubers and corms for control of aphids, whiteflies, psyllids, and mites. Not for use in greenhouses. (Group 23, REI 12h)

Ornazin (azadirachtin): See Azatin for more information.

Orthene (acephate): A systemic organophosphate insecticide that targets nerve and muscle tissue on contact. Registered for use as a foliar spray for beans, Brussels sprouts, cauliflower, celery, crisphead lettuce, mint and peppers to control caterpillars and other pests. Highly toxic to bees. (Group 1B, REI 24h)

Pasada (imidacloprid): See Admire for more information.

Permethrin* (permethrin): See Pounce for more information.

Perm-Up* (permethrin): See Pounce for more information.

PFR-97⁰⁶ (*Isaria fumosorosea Apopka Strain 97*): A naturally-occurring fungus that penetrates the cuticle of insect pests. Labeled for foliar and soil applications on greenhouse and field-grown vegetable crops to control a variety of insect pests. (No resistance classification, REI 4h)

Platinum (thiamethoxam): A selective systemic neonicotinoid. Works through ingestion, targeting nerve and muscle tissue. Registered as a soil treatment for brassicas, cucurbits, fruiting vegetables, leafy greens, roots, tubers, and corms for control of aphids, flea beetles, whiteflies, and other pests. Not for use in greenhouses or on plants grown for use as transplants. Highly toxic to bees. (Group 4A, REI 12h)

Portal (fenpyroximate): An insecticide and miticide that works on contact to disrupt pest species' ability to generate energy. Registered for use as a foliar spray on corn, cucumbers, fruiting vegetables, melons, potatoes, and snap beans for control of leafhoppers, mites, psyllids and whiteflies. Good rotational product to alternate with other chemistries. Low toxicity to bees and mammals. Extremely toxic to aquatic organisms. (Group 21A, REI 12h)

Pounce* (permethrin): A broad-spectrum pyrethroid insecticide that works as a nerve toxin. Registered for use as a foliar spray on a variety of crops for control of caterpillars and other pests. Extremely toxic to aquatic organisms and highly toxic to bees. (Group 3A, REI 12h)

Preferal⁰⁶ (*Isaria fumosorosea Apopka strain 97*): See PFR-97 for more information.

Prev-AM Ultra (sodium tetraborohydrate decahydrate): An insecticide, miticide and fungicide that utilizes borax to desiccate soft-bodied insects. Registered for use as a foliar spray on a range of crops to control aphids, caterpillars, thrips, whiteflies, and other pests. Also for control of downy mildew, powdery mildew, and late blight. (Group 25, REI 12h)

Proclaim* (emamectin benzoate): A selective avermectin insecticide, derived from a metabolite of the bacterium, *Streptomyces avermitilis*. Works through ingestion to target nerve and muscle tissue of lepidopteran larvae. Registered for use as a foliar spray with translaminar activity on brassicas, fruiting vegetables (except cucurbits), and leafy vegetables to control caterpillars. Not for use in greenhouses or on plants grown for use as transplants. Highly toxic to bees. (Group 6, REI 12h)

Prokil Cryolite (cryolite): A high rate per acre, fluorine-based insecticide that works as a stomach poison. Labeled for use as a foliar spray on broccoli, Brussels sprouts and cauliflower, melons, squash, and peppers to control several insect pests including flea beetles and some caterpillars. (Group un, REI 12h)

Pyganic⁰⁶ (pyrethrins): A broad-spectrum botanical pyrethrum. A fast-acting contact toxin with a short residual, it decays rapidly in sunlight and soils. Registered for use in field and greenhouse on a variety of crops to kill a wide range of insects. Highly toxic to bees. (Group 3A, REI 12h)

Pylon Miticide (chlorfenapyr): A pyrrole insecticide and miticide which works on contact and via ingestion, causing the pest to be unable to generate energy. Has translaminar activity. Registered for use as a foliar spray in greenhouses on tomatoes, eggplant, and peppers, for control of caterpillars, mites, and thrips. (Group 13, REI 12h)

Pyrethrum TR (pyrethrins + piperonyl butoxide): See Pyronyl Crop Spray for more information.

Pyronyl Crop Spray (pyrethrins + piperonyl butoxide): A broad-spectrum botanical pyrethrum mixed with a synergist (piperonyl butoxide) to improve efficacy. See Pyganic for more information.

Radiant (spinetoram): A nerve and stomach poison derived from the bacterium *Saccharopolyspora spinosa*; works on contact and by ingestion and has translaminar activity. Registered for use as a foliar spray on asparagus, brassicas, corn, cucurbits, herbs, legumes, and bulb, fruiting, leafy, root, and tuber vegetables for control or suppression of caterpillars, leafminers, psyllids, thrips, and certain beetles. Labeled for suppression of cabbage root maggot in leafy brassicas. Also has 2(ee) label for control of spotted-wing drosophila on fruiting vegetables. Toxic to bees for 3 hours following treatment. (Group 5, REI 4h)

Reaper* (abamectin): See Agri-Mek for more information.

Regent* (fipronil): A chloride channel antagonist that targets nerve and muscle tissue. Registered for in-furrow use on potatoes to control wireworms only. (Group 2B, REI 0h)

Requiem (*Chenopodium ambrosioides* extract): A contact insecticide and miticide derived from the herb *Chenopodium ambrosioides*; works on contact. Registered for use as a foliar spray on brassicas, bulbs, cucurbits, fruiting, leafy, root, tuber, and corm vegetables to control leafminers, thrips, and whiteflies. Low impact on beneficials. (No resistance classification, REI 4h)

Respect* (zeta-cypermethrin): See Mustang for more information.

Rimon (novaluron): An insect growth regulator that works through contact or via ingestion on immature stages to disrupt cuticle formation during molt, causing death. Best used on early stages, no activity against adult pests. Registered for use as a foliar spray on beans, cucurbits, fruiting vegetables, brassicas, sweet corn, potatoes, and sweet potatoes for control of a wide range of pests. Not for use in greenhouses, except on tomatoes. Low impact on beneficials. (Group 15, REI 12h)

Safari (dinotefuran): A systemic neonicotinoid that targets insect nerve and muscle tissue. Registered for use as a foliar spray on a variety of vegetable transplants grown in enclosed structures for control of aphids, leafminers, mealybugs, thrips, and whiteflies. Highly toxic to bees. (Group 4A, REI 12h)

Scorpion (dinotefuran): See Venom for more information.

Seduce⁰⁶ (spinosad): An insecticidal bait derived from the soil bacterium *Saccharopolyspora spinosa*; acts as a nerve and stomach poison. Attracts and kills insects feeding on or near the base of plants. Registered as a soil treatment on a variety of crops to control a wide range of pests. (Group 5, REI 4h)

Sefina (afidopyropen): See Versys. Labeled for use on cucurbits and other fruiting vegetables.

Sevin (carbaryl): A carbamate that targets nerve and muscle tissue primarily through contact activity. Registered for use as a foliar spray on asparagus, brassicas, cucurbits, legumes, roots, tubers, and fruiting and leafy vegetables to control a range of insect pests. For cutworms, granular formulation or liquid formulation may be used on some crops. Harmful to beneficials, highly toxic to bees, and extremely toxic to aquatic invertebrates. Note: long REI before detasseling corn. (Group 1A, REI 12h, 24h for sweet corn, 21 days before detasseling corn)

Shuttle O (acequinocyl): See Kanemite for more information.

Silencer* (lambda-cyhalothrin): See Warrior for more information.

Sivanto (flupyradifurone): A broad-spectrum insecticide in a new class of chemistries, the Butenolides. Acropetally systemic, and translaminar. Labeled for foliar applications in brassicas, cucurbits, fruiting, leafy, legume, root, and tuberous and corm vegetables for control of aphids, leafhoppers, whitefly, and in some crops, Colorado potato beetle, squash bugs, and psyllids. Also labeled for soil applications in cucurbits, fruiting vegetables, and leafy vegetables for control of aphids, leafhoppers, and whitefly. (Group 4D, REI 4h)

Skyraider* (bifenthrin + imidacloprid): See Brigade and Admire for more information.

Sluggo⁰⁶ (iron phosphate): A snail and slug bait and molluscicide. Disrupts feeding immediately and produces mortality in 3-6 days. Registered for use as a soil treatment to be scattered on moist soil around the perimeter of fields or banded in rows. May also be used in and around greenhouses; scatter around perimeter of greenhouse, or in and around pots. Low-risk material exempt from tolerances on food commodities. (No resistance classification, REI 0h)

Sniper* (bifenthrin): See Brigade for more information.

Stallion* (chlorpyrifos + zeta-cypermethrin): See Lorsban and Mustang for more information.

Steed* (bifenthrin + zeta-cypermethrin): See Brigade and Mustang for more information.

Suffoil-X⁰⁶ (mineral oil): A paraffinic oil insecticide, miticide and fungicide. Kills eggs, larvae and nymphs of insects and mites and adults of soft-bodied insects through suffocation. Registered for use as a foliar spray on a variety of crops to control a wide range of pests. Safe for use in greenhouses. (No resistance classification, REI 4h)

Surround⁰⁶ (WP) (kaolin): A naturally-derived clay protectant and insect repellent. Registered for use as a foliar spray on a variety of crops to repel certain beetles, leafhoppers, thrips, and other pests. (No resistance classification, REI 4h)

Swagger* (imidacloprid + bifenthrin): See Admire and Brigade for more information.

Talstar Nursery (bifenthrin): For greenhouse herbs only. See Brigade for more information.

Talus (buprofezin): An insect growth regulator that disrupts insect cuticle formation during molting through contact, ingestion, and vapor activity. Suppresses oviposition of adults and reduces viability of eggs. Mortality takes 3-7 days. Registered as a foliar spray on greenhouse tomatoes to control leafhoppers, mealybugs, planthoppers, and whiteflies. Long residual (up to 28 days). (Group 16, REI 12h)

Tempest* (bifenthrin + imidacloprid): See Brigade and Admire for more information.

Tersus (pyrethrins): See Pyganic for more information.

Thimet* (phorate): An organophosphate that is taken up by plant roots and acts systemically to target insect nerve and muscle tissue. Registered as a soil treatment in beans, corn, and potatoes for control of a range of pests. Highly toxic to bees. (Group 1B, REI 48h)

Timectin* (abamectin): See Agri-Mek for more information.

Tombstone* (beta-cyfluthrin): See Baythroid for more information.

Torac (tolfenpyrad): A mitochondrial electron transport inhibitor that acts on contact. Registered for use as a foliar spray on leafy vegetables to control leafhoppers, aphids, flea beetle, and thrips. Highly toxic to bees. (Group 21A, REI 12h)

Tracer (spinosad): For control of caterpillars, leafminers, thrips, and other pests on corn and soybeans only. See Entrust for more information.

Transform (sulfoxaflor): Sole member of a new resistance classification subgroup, active against sap-feeding pests. Labeled for use as a foliar spray on potatoes and root and tuber vegetables to control aphids, leafhoppers, potato psyllids and whitefly, and on succulent and dry beans to control aphids and plant bugs. Can be used as a rotational tool. Highly toxic to bees. (Group 4C, REI 24h). Note: After being cancelled in 2015, sulfoxaflor registrations have been reinstated by the EPA under limited-use restrictions.

TriAct⁰⁶ (neem oil): For use on vegetable transplants. See Azatin for more information.

Trident⁰⁶ (*Bacillus thuringiensis* subsp. *tenebrionis* strain SA-10): A bacterium-derived larvicide, labeled for control of Colorado potato beetle on potatoes, tomatoes, and eggplant. Must be ingested to be effective, so thorough plant coverage is essential. Most effective on young larvae in the first or second instar, or up to 1/4" in length. Apply as soon as eggs begin to hatch. After ingestion, larvae will stop feeding within a few hours and die within 2-4 days. Use of an adjuvant may improve efficacy, but avoid mixing with silicone-based surfactants. (Group 11, REI 4h) Note: Due to issues with formulation and shipping, Trident is not currently available.

Trigard (cyromazine): An insect growth regulator that acts by ingestion. Registered for use as a foliar spray on beans, brassicas, bulbs, cucurbits, leafy greens, peppers, and tomatoes for control of leafminers. Also labeled for Colorado potato beetle control in potatoes and suppression in tomatoes. (Group 17, REI 12h)

Trilogy⁰⁶ (clarified hydrophobic extract of neem oil): A broad-spectrum miticide and fungicide, containing oil extracted from seeds of the neem tree. Mite control depends on direct contact and requires thorough coverage. Registered as a foliar spray on a variety of crops for a range of pests. (No resistance classification, REI 4h)

Venerate⁰⁶ (Heat-killed *Burkholderia* spp.): A biological insecticide containing killed cells and fermentation solids of *Burkholderia* spp. Works by contact and ingestion to disrupt insect exoskeletons and interfere with molting. Registered for use as a foliar spray on most vegetables to control foliar feeding and plant-sucking pests. (No resistance classification, REI 4h)

Venom (dinotefuran): A neonicotinoid that targets insect nerve and muscle tissue. Acts by contact and ingestion. Becomes systemic when applied to soil, and has translaminar activity when applied to foliage. Registered for use as a foliar spray or soil treatment on cucurbits, fruiting vegetables, brassicas, leafy greens, and potatoes to control sucking and chewing insects. Highly toxic to bees. (Group 4A, REI 12h)

Verimark (cyantraniliprole): A systemic diamide that works by ingestion of treated plant material. Labeled for use in soil applications on

brassicas, cucurbits, fruiting, leafy, and tuberous and corm vegetables to control sucking and chewing insects, including caterpillars, aphids, flea beetles, leafminers, thrips, and cabbage maggot. Also labeled for control of seedcorn maggot in cucurbits. May also be used as a potato seed piece treatment. Highly toxic to bees. (Group 28, REI 4h)

Versys (afidopyropen): Chordotonal organ modulator acts to stop feeding immediately. Labeled for use on brassica head and stem vegetables, leaf petiole vegetables, leafy vegetables, pome fruit, and stone fruit. (Group 9D, REI 12 h)

Vetica (flubendiamide + buprofezin): Note: All flubendiamide registrations were canceled by the EPA in 2016. Growers may use up existing stock. See Belt and Talus for more information.

Voliam Flexi (chlorantraniliprole + thiamethoxam): See Coragen and Actara for more information on active ingredients in this product.

Vulcan* (chlorpyrifos): See Lorsban for more information.

Wydate* (oxamyl): A systemic carbamate insecticide and nematicide that is taken up by plant roots and acts on contact or by ingestion to target nerve and muscle tissue. Registered for use as a foliar spray or soil treatment on carrots, some cucurbits, eggplant, peppers, tomatoes, and sweet potatoes for control of nematodes and several insect pests. Labeled for control of brown marmorated stink bug in pepper and tomato. Highly toxic to bees, and extremely toxic to birds, fish, and mammals. (Group 1A, REI 48h)

Warhawk* (chlorpyrifos): See Lorsban for more information.

Warrior* (lambda-cyhalothrin): A broad-spectrum pyrethroid insecticide that targets nerve and muscle tissue. Registered for use as a foliar spray on brassicas, cucurbits, sweet corn, fruiting vegetables, legumes, lettuce, bulb onions, garlic, and tuberous and corm vegetables to control a range of pests. May be applied before, during, or after planting for cutworm control. Highly toxic to bees, and extremely toxic to aquatic organisms. (Group 3, REI 24h)

Whirlwind* (chlorpyrifos): See Lorsban for more information.

Wrangler (imidacloprid): See Admire for more information.

XenTari⁰⁶ (*Bacillus thuringiensis* subsp. *aizawai*): A derivative of the bacterium *Bacillus thuringiensis* subsp. *aizawai*. Works via ingestion, stopping feeding within an hour and inducing mortality within 3 days. Registered for use in field or greenhouse as a foliar spray on most vegetables for the control of caterpillars. May be especially useful for control of diamondback moth larvae that are resistant to *Bt kurstaki* or other products. Toxic to green lacewing and predatory mite (*Metaseiulus occidentalis*) (Group 11, REI 4h)

Xpedient* (bifenthrin): See Capture for more information.

Yuma* (chlorpyrifos): See Lorsban for more information.

Zeal (etoxazole): A mite growth regulator that works as an ovicide and larvicide. Registered for use as a foliar spray on cucurbits, mint, eggplant, and peppers to control mites. (Group 10B, REI 12h)

Zoro* (abamectin): See Agri-Mek for more information.

Zyrate (esfenvalerate): See Asana for more information.

WEED MANAGEMENT

Weeds compete with crops for water, light, space, and nutrients and can significantly reduce crop yields through this competition for resources. In general, weed management is more important in the earlier part of the crops life. Crops

tend to be more vulnerable to the effects of competition when they are establishing, and some have critical weed-free periods defined. Weeds can also harbor insects and diseases, as well as interfere with harvesting and other farm operations. Weed management options include physical, cultural, and chemical controls. For most growers, integrating these three options provides the best overall control of weeds.

Weed control focuses on stopping weeds from establishing, eradicating weeds that have established, and preventing weeds from making seeds which will add to the soil seed bank and create increased weed pressure in the future.

Weeds are not all equally competitive. It can be helpful to prioritize weeds by their impact to the crop or their potential to spread aggressively when planning weed management. Proper identification of weeds can be crucial to successful control. Different types of plants (grass, broadleaf, rush, or sedge) respond differently to different controls strategies. Understanding the weed life cycle is also important to select the most effective timing of the control.

Weed Life Cycles

Annual plants complete their life cycle in one year and reproduce by seed. They germinate from seeds, grow to maturity, flower, and make seeds all within a single growing season. **Biennial plants** take two years to complete their life cycle. They typically germinate from seeds and grow vegetatively in the first year, then enter a period of dormancy over the winter. They flower and make seeds during the following growing season. **Perennial plants** can live for many years and may reproduce by seed, runners, rhizomes, etc.

Farm practices can impact weed populations on your farm. For example, growers who practice no-tillage or reduced-tillage will typically see the type of weeds shift from annual weeds to perennial weed species. Weed maps of field areas are extremely helpful in planning weed control strategies. A weed map can illustrate problem areas so that growers can target specific problems in specific areas, and help plan for future crop rotations. A weed map can also indicate shifts in weed pressure if kept continuously over years and indicate the possible need for a strategy change.

Physical/Mechanical Weed Management

Physical weed management includes hand weeding and cultivation. Hand weeding is expensive but effective. The availability and cost of labor are key considerations, although it is common to perform some hand weeding in almost all vegetable crops. When pulling weeds or using hand tools, minimize soil disturbance to avoid moving more weed seeds close to the soil surface where they can more easily germinate.

Cultivation is an important component of weed control in vegetables, particularly when the use of herbicides and/or mulches is to be minimized or avoided. In general, weeds are most effectively cultivated shortly after they germinate, and crops are most sensitive to weed pressure during their early stages of growth. Thus, cultivation is most critical early in the growing season. Also, weeds will die more easily if the sun is out and the soil is not wet. Mechanical methods should be combined with cultural practices such as crop rotation, composting of manure, and mowing of headlands to keep nearby weeds from going to seed. In addition, it is

Table 26: Information about Insecticides and Miticides
 Pesticides listed in **bold** were used as examples; their labels and MSDS were consulted for the data given in this table. This information may vary slightly for the other products listed. No preference is indicated by this distinction. The symbol * indicates a federally restricted use pesticide. Unmarked active ingredients may have state restrictions; always check a product's registration status in your state before using. The symbol ^{oe} indicates a pesticide that has been listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. Mixtures are listed under all active ingredients and indicated with an (M). When tank mixing pesticides, mix in the proper order. The order is: Wettable Powders (WP), Water Dispersible Granules (WDG), Flowables (F) (DF) (SC), Water-dispersible liquids (AS), Emulsifiable Concentrates (EC), and Solutions (S). Always follow the pesticide label when using adjuvants such as spreader stickers, surfactants, etc.

Active Ingredient	Trade Name and Formulations	Signal Word	Resistance Group (IRAC code)	Dermal LD ₅₀	Oral LD ₅₀	Toxicity to bees
abamectin*	Abacus; Abamex; Agri-Mek SC ; Athena (M); Clinch Ant Bait; Nufarm Abamectin 0.15EC; Reaper 0.15EC, ClearForm; Tide Timectin 0.15EC; Zoro Miticide/Insecticide	W	6	>2,000	310	H
acephate	Acephate 90 Prilil, 90 WDG, 90 WSP; Orthene 97	C	1B	>2,000	688	H
acequinolyl	Kanemite 15SC ; Shuttle 0	C	20B	>2,000	>5,000	L
acetamiprid	Assail 30SG , 70WP	C	4A	>2,000	805	M
alpha-cypermethrin*	Fastac EC	D	3A	>5,000	>210 - <1,050	H
afidopyroen	Inscalis, Sefina, Versys	C	9D	>2,000	1,320-6,690	L
azadirachtin	Amazin Plus 1.2% ME ^{oe} ; Aza-Direct ^{oe} ; AzaGuard ^{oe} ; Azatin 0^{oe} ; XL; Azatrol EC ^{oe} ; Azera ^{oe} (M); Eozin Plus 1.2% ME ^{oe} ; Molt-X ^{oe} ; Neemix 4.5 ^{oe} ; Omazin 3%EC	C	un	>2,000	>5,000	L
<i>Bacillus thuringiensis</i> subsp. <i>aizawi</i>	XenTari^{oe}	C	11	>2,000	>5,000	L
<i>Bacillus thuringiensis</i> subsp. <i>israelensis</i>	Gnatrol WDG^{oe}	C	11	>5,000	>5,000	L
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i>	CoStar ^{oe} ; Deliver ^{oe} ; Dipel ES; Dipel DF^{oe} ; Javelin WG ^{oe}	C	11	>2,020	>5,000	L
<i>Bacillus thuringiensis</i> subsp. <i>tenebrionis</i> strain SA-10	Trident ^{oe} (currently off the market due to formulation and shipping issues)	C	N/A	--	--	M
<i>Beauveria bassiana</i>	Botanigard ES, 22WP; Mycotrol ESO	C		--	--	L
beta-cyfluthrin*	Aztec 2.1G (M); 4.67G (M); Baythroid XL ; Defcon 2.1G (M); Leverage 360 (M); Tombstone, Helios	W	3	>2,000	647	H
bifenazate	Acramite 50WS ; Floramite SC	C	un	>5,000	>5,000	M
bifenthrin*	Athena (M); Bifenture EC, 10DF; Brigade 2EC , WSB; Brigadier (M); Capture LFR; Discipline 2EC; Empower 2 (M); Fantare ES; Hero (M); EW (M); Match-Up (M); Skyraider (M); Sniper, Helios, LFR; Steed (M); Swagger (M, EPA rated D); Talstar Nursery; Tempest (M); Xpedient Plus	W	3A	nil	262	H
bugrofezin	Talus 70DF ; Vetrica (M)	C	16	>2,000	>5,000	L
<i>Burkholderia</i> spp. (heat killed) Strain A396 and spent fermentation media	Venerate XC^{oe}	C	N/A	>5,050	>5,000	M
capsicum oleoresin extract	Captiva (M)	C	N/A	>2,000	>5,000	L
carbaryl	Carbaryl 4L; Sevin XLR Plus , 4F	C	1A	>4,000	699	H
<i>Chenopodium ambrosioides</i> extract	Requiem EC	C	--	>2,020	>5,000	L
chlorantraniliprole	Besiege* (M); Coragen , Durivo (M); Voliam Flexi (M)	C	28	>5,000	>5,000	L
chlorfenapyr	Pylon Miticide	C	13	>2,000	560	M
chlorpyrifos*	Bolton (M); Chlorpyrifos 15G, 4E AG; Cobalt (M); Cobalt Advanced (M); Hatchet; Lorsban 4E , 15G, 50W, 75WG, Advanced; Match-Up (M); Nufos 4E; Stallion (M); Vulcan; Warhawk, Clearform; Whirlwind; Yuma 4E	W	1B	>1,000	300	H
<i>Chromobacterium subsugae</i>	Grandveo^{oe}	C	--	>5,000	>5,000	M
cinnamon oil	Ecotrol G2^{oe} (M)	C	N/A	--	--	L
Clarified hydrophobic extract of neem oil	Triact 70 ^{oe} ; Trilogy^{oe}	C	--	>2,000	>5,000	M
clothianidin	Belay , 50WDG	C	4A	>5,000	>3,900	H
clove oil	Ecotrol G2^{oe} (M)	C	N/A	--	--	L
cryolite	Prokil Cryolite 96	C	un	--	--	L
cyantraniliprole	Exirel ; Verimark	C	28	>5,000	>5,000	H
cyclaniliprole	Harvanta	C	28	>2,000	>2,000	H
cyflumetofen	Nealta Miticide	C	25	>5,000	>2,000	L
cyromazine	Trigard	C	17	>2,010	4,460	L
deltamethrin*	Delta Gold	D	3A	>2,000	42.9	H
diazinon*	Diazinon AG500 , 50W, AG600 WBC	C	1B	>2,000	787	H
diflubenzuron*	Dimilin 25W	C	15	>20,000	>10,000	L
dimethoate	Dimate 4EC; Dimethoate 4EC , 400	W	1B	1,000	60	H
dinotefuran	Safari 20SG ; Scorpion 35SL; Venom	C	4A	>2,000	>2,000	H
esfenvalerate*	Proclaim	C	6	>2,000	1,516	H
ethoprop*	Asana XL ; Z,yrate (M)	W	3	>2,000	458	H
	Mocap 15G , EC, 15G Lock n Load	D	1B	166	15.9	H

Table 26: Information about Insecticides and Miticides (continued)						
Active Ingredient	Trade Name and Formulations	Signal Word	Resistance Group (IRAC ⁶ code)	Dermal LD ₅₀	Oral LD ₅₀	Toxicity to bees
etoxazole	Zeal, WDG	C	10B	>5,000	>5,000	L
fenpropathrin*	Danitol 2.4EC	W	3	>500 - <5,000	>50 - <500	H
fenproximate	Akari 5SC, Portal XLO	W	21A	>2,000	810	L
fipronil*	Regent 4SC	W	2B	382	336	H
flonicamid	Beleaf 50SG	C	9C	>2,000	>2,000	L
flubendiamide	Belt SC; Vetica (M)	C	28	>4,000	>2,000	L
flupyradifurone	Sivanto 200SL	C	4D	>2,000	>2,000	L
gamma-cyhalothrin*	Bolton (M); Cobalt (M); Consero (M); Declare	C	3A	>5,000	>2,250	H
garlic oil	Captiva (M)	C	N/A	>2,000	>5,000	L
geraniol	Ecotrol Plus ⁰⁶ (M)	C	N/A	--	--	M
imidacloprid	Admirer Pro; Advise Four; Alias 4F; AmTide Imidacloprid 2F, 4F; Brigadier (M); Couraze 2F, 4; Leverage 360 (M); Macho 2.0FL, 4.0FL; Mallet 75WSP; Marathon 1% Granular, 60WP, II; Midash Forte; Montana 2F, 4F; Nuprid 2SC, 4F Max; Pasada 1.6F; Skyraider* (M); Swagger* (M, EPA rated D); Tempest* (M); Wrangler	C	4A	>2,000	4,143	H
indoxacarb	Avaunt	C	22	>5,000	687	H
insecticidal soap	See potassium salts of fatty acids					
iron phosphate	Sluggo; Slug and Snail Bait ⁰⁶	C	N/A	>5,000	>5,000	L
<i>Isaria fumosorosea</i> Apopka Strain 97 (formerly <i>Paeclomyces fumosoroseus</i>)	PFR-97 20% WDG ⁰⁶ , Preferal ⁰⁶	C	M	--	--	M
kaolin	Surround WP ⁰⁶	C	N/A	--	>5,000	L
lambda-cyhalothrin*	Besiege (M); Cobalt Advanced (M); Endigo ZC (M); Grizzly Too; Lambda-cy EC; Lambda-T2; Silencer 1EC; Warrior II with Zeon	W	3A	>2,000	180	H
malathion	Eyfanon ULV AG; Malathion 57EC, 5, 5EC, 8F, 8 Aquamul	W	1B	>2,000	650	H
metaldehyde	Deadline M-Ps, Bullets, GTS	C	N/A	>5,050	>5,000	L
<i>Metathizium anisopliae</i> Strain FS2	Met52 EC	C	N/A	>5,000	--	L
methomyl*	Lannate LV, SP; Nutrin LV, SP	D	1A	>2,000	49	H
methoxyfenozide	Intrepid 2F	C	18	>2,000	>5,000	L
Mineral (or paraffinic, or petroleum) oil	Damoli; Organic JMS Stylet Oil ⁰⁶ ; JMS Stylet Oil; Mite-E-Oil; Suffoil-X ⁰⁶	C	M	>2,000	>5,000	L
neem oil	See clarified hydrophobic extract of neem oil					
novaluron	Rimon 0.83EC	W	15	>2,000	>5,000	L
oxamyl*	Vydate L, C-LV	D	1A	>5,000	9	H
peppermint oil	Ecotrol Plus ⁰⁶ (M)	C	N/A	--	--	M
permethrin*	AmBush 25W; Arctic 3.2EC; Permethrin 3.2AG; Perm-up 3.2EC; Pounce 25WP, 1.5G	C	3A	>2,000	1,100	H
phorate*	Thimet 20G Lock n Load, 20G Smartbox, 20G EZ Load	D	1B	86	5	M
phosmet	Imidan 70W	W	1B	>2,000	258	H
potassium salts of fatty acids	DES-X ⁰⁶ ; M-Pede ⁰⁶	W	M	--	--	L
pymetozine	Fulfill	C	9B	>2,000	>5,000	L
pyrethrins	Azera ⁰⁶ (M); Evergreen EC 60-6 (M); Pyganic EC1.4 ⁰⁶ ; Pyganic EC5.0fl ⁰⁶ ; Pyrethrum TR (M); Pyronyl Crop Spray (M); Tersus C	C	3A	>2,000	>2,000	M
pyriproxyfen	Distance IGR; Esteem 0.86EC; Knack IGR	C	7D	>2,000	3,773	L
rosenmary oil	Ecotrol Plus ⁰⁶ (M)	C	N/A	--	--	M
sodium tetraborohydrate	Prev-AM Ultra	W	8D	>2,000	>5,000	L
soybean oil	Captiva (M); Golden Pest Spray Oil ⁰⁶	C	N/A	--	--	L
spinetoram	Radiant SC	C	5	>5,000	>5,000	M
spinosad	Blackhawk; Consero* (M); Entrust ⁰⁶ ; Entrust SC ⁰⁶ ; GF-120 Naturalyte ⁰⁶ ; Seduce ⁰⁶ ; Tracer	C	5	>5,000	>5,000	M
spirotrienolol	Oberon 2SC, 4SC	C	23	--	>2,000	M
sulfoxalor	Kontos Greenhouse and Nursery; Movento Closer; Transform	C	23	--	>2,000	M
sulfur	Bonide Garden Dust; Microfine sulfur ⁰⁶ ; Microthiol Dispers ⁰⁶	D	4C	>5,000	>2,000	H
tebufenozide	Conform 2F	C	M2	2,000	>2,000	L
tebufenpyrifos*	Aztec 2.1G (M); 4.67G (M); Defcon 2.1G (M)	C	18	>5,000	>5,000	L
tefluthrin*	Force CS, 3G, 3G Smartbox	W	3A, 1B	>2,000	132	L
tebufos*	Counter 20G Smartbox	D	3A	2,000--5,000	174	H
thiamethoxam	Actara 25WDG; Cruiser 5FS, Maxx Potato (M); Vibrance Quattro (M); Durivo (M); Endigo* ZC (M); Platinum, 75SG; Voliam Flexi (M)	C	4A	>2,000	>5,000	H
thyme oil	Ecotrol G2 ⁰⁶ (M)	C	N/A	--	--	L
tofenpyrad	Torac	W	21A	>2,000	83	H
zeta-cypermethrin*	Hero (M), EW (M); Holster, Mustang, MXXX, Respect EC; Stallion (M); Steed (M)	W	3A	>2,000	234	H

1= Insecticide Resistance Action Committee

imperative that cultivation tools be properly adjusted. Here is a summary of some commonly used weed control equipment and practices:

Blind cultivation is performed after crops have been planted, over the top of them, so that both in-row and between-row areas are cultivated. To minimize crop damage, this should be done before the crop has emerged and/or once it is well rooted. Slightly deeper planting depths and slightly higher plant populations are recommended to compensate for some crop loss that may occur. Very tender crops such as leafy greens are not amenable to this technique, but a surprising array of crops are suitable for blind cultivation, including corn, cucurbits, beets, etc. depending on stage of growth and equipment used.

Between-row cultivation can be performed with varying degrees of aggressiveness, so that soil may or may not be pushed into the row to obtain some between-row weed control. Commonly used cultivation setups consist of a shank (either straight, C-, or S-shape) attached to a toolbar, with a cultivating tool (shovel, sweep, knife, hilling disc, etc.) attached to the bottom. The more curve to the shank, the more it will vibrate and flex in the soil. Trip-shanks have a release mechanism that allows the shank to pop up when it hits a rock. Shanks can be arranged on multiple toolbars to offer complete coverage between multiple rows in beds. Planting crops using the same row spacing will make it easier to cultivate with a single set up by minimizing equipment adjustments for different crops.

There are many kinds of tools that can be attached to the shanks, and these should be selected to disturb only as much soil as is needed to kill the weeds present. In general, one starts the season with smaller, shallower tools to kill small weeds when the crop is small; as the season goes on, if larger weeds are present, then more aggressive tools are needed, and as the crop grows it is possible to more aggressively push soil into the row without causing damage. For example, shovels might be followed by sweeps and then hilling discs. Another strategy is to adjust the angle of cultivating tools such as hilling discs or rolling cultivators as the season goes on. Start by pulling soil away from the row when cultivating a young crop; that creates a small hill that can be pushed back into the row when the crop is a bit older to bury weeds.

In small and/or tender crops like leafy greens, shallow tools are needed that will not move soil into the row and cause damage. A side-knife (or beet-hoe) may be used to cultivate horizontally next to the crop, just below the surface.

Tine weeders (Einbock, Kovar, Lely) have multiple rows of flexible metal tines that cover the entire soil surface, wiggling slightly as they are pulled along, uprooting or dislodging very small weeds. They work best at relatively high speeds, and the wide span of the tool makes cultivation quick. They are rear-mounted and available in many widths. The tension on the tines can be adjusted on some units or by the pressure on the 3-point hitch on other units. Gauge wheels can be used to maintain uniform depth. Work best in friable soils free of rocks, and when weather allows weeds to dry out on soil surface after uprooting.

Rotary Hoes (Yetter, Deere) have many narrowly-spaced metal wheels each with about 16 curved teeth that work the surface of the soil. Used within the first few weeks of planting

less tender crops like corn or beans, they destroy weeds that have just germinated. Ground-driven, spring-loaded wheels do little damage to the crop and work well at high speeds on dry, rock-free soils with little residue. They are rear mounted, in many widths. The teeth, or spoons, lose their effectiveness if not sharp.

Basket weeders (Buddingh) are relatively high-speed, between-row cultivators good for control of small weeds in narrow rows when crop is small. The wire baskets work the soil surface and do not move soil into the row, but they don't work well in crusted or rocky soil. The front set of baskets are ground driven, and they turn the rear set of baskets a bit faster via a chain and gearing, causing scuffing of the soil. These are available in 2- to 6-row units that can be rear or belly-mounted.

Finger weeders (Buddingh) Finger weeders consist of steel cone wheels that are ground-driven by spike tines on the bottom, with rubber fingers on the perimeter. The rubber fingers work the soil just below the surface, uprooting small weeds located very close to the crop. Finger weeders work best for single rows, to control small weeds in dry, friable soil with few rocks or residues. Clay soils may stick to fingers.

Spring-hoe, torsion weeders, and spyder weeders (Bezzarides) are flexible blades and square metal stock that disturb soil around base of plants, and ground-driven spyder wheels with staggered teeth in an uneven pattern that break clods and throws soil into row, or pull it away, depending on the angle. These can be toolbar-mounted, either under the belly or in the rear. They can be used together, separately, or in conjunction with other cultivators.

Row crop cultivators (many brands are available) have gangs of S-shanks with sweeps that break up the soil while destroying small to moderate-sized weeds. The gangs work behind the tractor between the rows at uniform intervals. Shields may be added to protect the crop from moving soil, and a fertilizer hopper can be used for sidedressing during cultivation.

Rolling cultivators (Lilliston, BHC) have gangs of soil-driven 'spider wheels' that mount independently on a toolbar. The angle that they work the soil, and thus their aggressiveness, is usually adjustable. The number of gangs grouped together determines cultivator width, and these are usually rear-mounted, but pairs of gangs may be belly mounted to work a row or two. Soil can be thrown into row to bury small weeds or to form hills, depending on angle of the gangs. This is a relatively heavy, aggressive tool.

Wiggle hoe (Friday) is an in-row cultivator that uses hand-steered side knives controlled by an operator who moves them in and out of the row. Knives can reach very close to the row and eliminate the weeds, but if the operator isn't careful, the crop can be damaged. Good for irregular plant spacing in the row or between rows.

Reigi weeders are a relatively new tool that also requires a rear operator who steers a pair of rotating horizontal wheels in and out of the crop row. The wheels are turned by a PTO-driven belt, and they have stiff tines on them that root out weeds. The wheels come in several sizes useful for various row spacings, and the units come in 1 or 2-row models.

These are very effective for killing weeds in and next to the row in widely spaced crops like pumpkins, first-year strawberries, or sweet corn with a lot of skips.

Flame weeders can be used to kill weeds before planting without causing soil disturbance that brings up new weed seeds, after the crop has been planted (but before it emerges), inter-row weeding, and for stale seed bed preparation. Flame weeding, also known as thermal weeding or flame cultivation, exposes plants to brief periods of high temperature that causes the water in the plant tissue to expand rapidly, rupturing plant cells and leading to tissue damage. Plants are not burned or incinerated, but “blanched”. They will not show symptoms of injury for several hours after exposure. Some weeds, such as purslane, can tolerate high temperature, and grasses with their growing points below ground are not controlled by flaming. When weeds are moist from rain or dew, more heat (a slower tractor or walking speed) will be necessary.

Like with contact herbicides, flaming kills weeds without soil disturbance, it is ideal for stale seedbeds. Once broadleaf weeds reach the three-leaf stage, they should be flamed to prevent them from growing too large. For longer lasting weed control, apply the final flaming as late as possible prior to crop emergence after seeding or just prior to transplanting.

Hand-held propane torches are commonly used to flame single rows at a time, but multi-row bed-flamers and tractor-mounted flamer kits are also available. Larger units require greater attention to safety during construction and operation. Safety is a big issue with flaming. Consult with a gas professional if constructing your own flaming unit. Do not mount propane tanks intended for stationary use onto tractors. Flame against the breeze and avoid areas with dry residues or dry hedgerows. Liability concerns may hinder the use of flaming.

Cultural Weed Management

Cultural options include cover crops, fallowing, plant competition, mulches, soil preparation, stale beds, and crop rotation.

Cover Crops alone do little to reduce overall weed populations. A dense stand will provide weed suppression while it is growing. They can also slow the warm-up of soil and provide shade, both helping to slow weed seed germination and reduce the soil seed bank over time. Perennial weeds will be largely unaffected. Soil disturbances between short cycles of cover crop growth are effective. The tillage kills germinated weeds and also moves weed seeds up to near the soil surface where they can germinate prior to the next disturbance. Through these cycles, the objective is to encourage weed seed germination but not to allow further weed seed production.

Fallowing is not planting a field with the intention to reduce weed seed populations. For annual and biennial weeds, physical weed control is best. Repeated soil disturbances (disking, rototilling) before weeds go to seed, even in the absence of a cover crop, will reduce the weed seed bank of a field.

Plant competition can reduce weed pressure. Use of transplants, rather than direct seeding where possible, will allow the crop to get a jump on the weeds and provide shading of the soil which will delay weed emergence and competition. Decreasing the space between crops will also increase soil shading. Overall, the more rapidly a crop can

cover the soil ahead of weed emergence, the more competitive that crop will be.

Mulches are often used to control weeds. Mulches can be organic (straw, hay, grass clippings, dead cover crops) or inorganic (plastic). Organic mulches are effective if they are thick enough to keep weeds from emerging through them (usually at least 2-3"). Downsides of organic mulches are that they can be expensive, they slow soil warm up or reduce soil temperatures, and they can harbor animal pests. Cooler soil temperatures can be a problem in warm season crops. It is recommended that the mulch application be delayed to allow the soil to warm up sufficiently for the crop. Black plastic mulches will warm soil and eliminate weed pressure. However, weeds emerging through the planting holes and between strips of plastic mulch can still reduce yields if not controlled. Infra-Red Transmitting (IRT) mulches are less effective than black plastic for controlling weeds, and clear mulches can enhance weed growth. Some growers plant cover crops between plastic mulch strips as “living mulch”, but these cover crops can also compete with the crop. Killing the living mulch before the crop is planted, mowing the mulch on a regular basis, or using raised beds will help to reduce but not eliminate competition. See the section on using herbicides in combination with plastic mulches later in this section.

Proper soil preparation can influence weed emergence. Soils which are rough and less firmly packed will yield fewer weeds than those that are more finely worked, more compacted, and more uniformly moist.

Stale seedbed or summer fallowing is performed on fields that have been prepared for planting, either in the spring before a crop is sown, or in the summer after a spring crop but before a fall crop. The soil is then lightly disturbed on a regular basis to kill small weeds as they emerge, without bringing up new weed seeds from below the top few inches of soil. Early in the year, broadleaves will not be controlled if they have not yet emerged, so a summer fallow works better on them. Perennial weeds may be weakened but not killed. Tools that can be used for this practice include chain-drag, spring-tooth harrow, light-weight disc harrows, or tine weeders. See additional information on the stale seedbed technique later in this section.

Crop rotation can be a tool for managing weeds. Weed species present tend to be most like crop planted. Examples include grasses in corn, winter annuals with early-planted crops, and perennial weeds with perennial crops. Rotating crops among these groups will tend to disrupt this trend.

About Herbicides

Herbicides are chemicals designed to control weeds. The use of these materials must be exact for satisfactory results. Proper rate selection, timing of application, activation, and observance of all precautions on the label must be followed to obtain optimum performance. Each herbicide controls certain weeds or families of weeds. Therefore, knowledge of the type of weed species present in the field is essential for good weed control. Once the weed problem is known, select the proper herbicide.

Herbicides can be **systemic**, meaning that they are absorbed and moved throughout the plant, while others are contact herbicides, meaning that they only affect the plant tissue they come into contact with.

Preemergence Herbicides (PRE) - These herbicides are applied prior to the emergence of weeds. In general, they work by preventing weeds that are germinating from seeds from growing, but some can also act on perennial plants that spread by rhizomes, tubers, and stolons. Application is timed to coincide with when the target weeds are about to begin germinating. These herbicides prevent new weeds from establishing, but most will not impact weeds that are already emerged.

Preplant - These herbicides are applied before the crop is planted. They can be preemergence products that are incorporated into the soil, or applied to control existing vegetation.

Postemergence Herbicides (POST) - These herbicides work on actively growing weeds. They can be absorbed by the leaves or roots of the plants, depending on the chemical.

Adjuvants - These products are added to a pesticide mixture to improve its effectiveness. They include surfactants, stickers, penetrants, compatibility agents, etc. Pesticide labels may list specific types of adjuvants that will maximize effectiveness of the pesticide. Be sure to use the proper category of adjuvant if the manufacturer makes a specific recommendation.

When adjuvants are recommended, it is because research has shown that their addition increases efficacy of the herbicide. If the label advocates the usage of an adjuvant, do not omit the adjuvant solely to save money. The most common adjuvants used with herbicides are nonionic surfactants (NIS) and crop oil concentrates (COC) which can consist of petroleum, vegetable, or methylated vegetable or seed oils. They increase penetration of the herbicide through the leaf cuticle.

Herbicides and Crop Rotation Constrictions

Some herbicides can have long-lasting activity. Many herbicides have crop rotation constrictions where they have been applied. For example, Devrinol has a 60-day plantback interval for leafy greens. Check the label of each product for details.

Toxicity of Herbicides

The toxicity of pesticides varies by the active ingredient, concentration of active ingredient, and the formulation of the product (e.g. liquid, powder, etc.). The toxicity of a pesticide is expressed in terms of oral (administered internally) and dermal (applied to the skin) LD₅₀. LD₅₀ is the dosage of poison that kills 50% of test animals (usually rats) with a single application of the pesticide product and is expressed as mg/kg of body weight. The lower the LD₅₀ value, the more toxic the material.

The acute (short-term) toxicity of the formulated product is conveyed on label by a "signal word" stated on the front page.

DANGER - pesticide product is highly toxic by at least one route of exposure. It may be corrosive and cause irreversible damage to the skin or eyes. If the product is highly toxic if eaten, absorbed through the skin, or inhaled, then the word "POISON" must also be included in red letters.

WARNING - pesticide product is moderately toxic if eaten, absorbed through the skin, inhaled, or it causes moderate eye or skin irritation.

CAUTION - pesticide product is slightly toxic if eaten,

absorbed through the skin, inhaled, or it causes slight eye or skin irritation.

General Principles for Safe Use

- Know the herbicide. Read the label.
- Check the output of sprayer frequently.
- Replace worn nozzles. It may be necessary to replace them several times a season if the sprayer is used constantly.
- Rinse spray equipment immediately after use. Use one sprayer for herbicides and another for insecticides and fungicides.
- For restrictions on rates, timing and crops for which the herbicide is approved, see Table 27, page 108.
- For degree of susceptibility of each weed to a specific herbicide, see Table 28, page 109.
- For limitations and special requirements of the herbicide, refer to the product label (or supplemental label).

Rate Selection

Always check the label to determine the proper rate to apply. For most soil-applied herbicides, knowledge of the type of soil and the percentage organic matter usually determines the rate. Generally, the more clay and/or organic matter present in the soil, the higher the herbicide rate necessary for good weed control. For postemergence herbicides, the type of weed, as well as its size, will usually determine the rate.

Incorporation of Herbicides

Some herbicides must be incorporated into the soil to be effective. Herbicides are incorporated because they are volatile and evaporate into the air if left on the soil surface or they will decompose when exposed to sunlight. Herbicides differ in their incorporation requirements; check the product label for the manufacturer's requirements.

Herbicide Sprayer Systems

- Select a sprayer and pump that can deliver a volume of 20-50 gallons per acre. Most herbicides are applied at rates of 20-40 gallons of water per acre. Pressures of 20-40 p.s.i. at the nozzle are recommended for most herbicides. Higher pressures result in finer droplets and increase the chance for more drift. Lower pressures sometimes cause uneven spray patterns.
- Use 50-mesh screened filters for nozzles and suction lines.
- Select 80° or 73° flat fan nozzles. Because of wear, brass tips used exclusively for applying wettable powders should not be used on more than 30 acres before being replaced. Use stainless steel or hardened stainless steel tips for longer wear. Stainless steel nozzle tips are more than twice the cost of brass tips but last about 20 times longer. Hardened stainless steel tips are only slightly more expensive than stainless steel tips but last three times longer. Ceramic nozzles are the most durable.
- Calibrate sprayers frequently and check for wear, especially when wettable powders have been used.

Resistance Management

Pesticide resistance is an inheritable (genetic) characteristic of a pest that makes it less sensitive to a pesticide. Repeated use of the same pesticide (or pesticides with the same mode of action) over time kills pests that are susceptible to the

pesticide and leaves behind individuals that are less sensitive. These then reproduce and pass on the genes that let them survive pesticide exposure to their offspring. With herbicides, this usually takes several years to accomplish. This is because of the seed bank in the soil that preserves individuals that are not resistant for many years.

International groups have been founded for a cooperative approach to resistance management. They have assigned group numbers to pesticides to help growers make decisions on how to rotate pesticides. They are based on mode of action—how and where the chemicals in the pesticide work on the target. The Herbicide Resistance Action Committee (HRAC) and The Weed Science Society of America (WSSA) have both developed similar classification systems of herbicides. WSSA uses numbers instead of letters to designate the categories. A key step in resistance management is to minimize the continuous use of herbicides with the same mode of action through rotations and combinations of products. One of the purposes of these classification systems is to make it easier for farmers and farm advisors to understand which herbicides share the same mode of action without having to actually know the biochemical basis.

Most labels now come with a group number assigned to them. Some active ingredients are available under several different product names, and sometimes different active ingredients have the same mode of action.

Resistance management may include alternating or sequencing products with different modes of action or limiting the total number of applications per season. When selecting herbicides for resistance management, use the group number as your guide and NOT the product name or active ingredient.

The most effective way to extend the useful life of an effective product is to rotate herbicides within fields if the same crop is grown or to rotate crops so that different herbicides might be used in following years. The most common weed resistance issue that we have in New England is common lambsquarters that is resistant to atrazine. To help select pesticides with a different mode of action, see chemical resistance groupings in Table 27, page 108.

Once a weed develops resistance to a group of pesticides with a particular mode of action, a higher rate of the same or a similar chemical from the same group usually will not control the weed.

There are many other techniques that can help delay the onset of resistance. Using other options and recognizing weeds that may be resistant is critical.

- Integrate chemical control with effective cultural, mechanical, and physical options.
- Scout fields so that you are aware of what is not controlled and can take steps to control the escaped weeds.
- Good rate selection, spray coverage, and herbicide activation helps do the job right the first time and avoids unnecessary repeat applications: use the proper size nozzles and the correct angle or orientation and the right amount of water per acre.
- Time postemergence applications so that the weeds are at the right stage of growth.

NOTE: The group number is specific for each type of pesticide (insecticides, herbicides, and fungicides). For example, there is no problem when using material from the herbicide Group 1 and an insecticide or fungicide from Group 1.

Groundwater Concerns

The following herbicides have the potential to impact groundwater due to their chemical characteristics and toxicological profile and have been discussed in the crops sections. Check with your state for restrictions of their use in sensitive areas. For example, Massachusetts has Zone II designations and regulations pertaining to the use of these herbicides in those areas.

Atrazine (Aatrex)	Fluthiacet-methyl (Cadet)
Bentazon (Basagran)	Metolachlor (Dual Magnum)
Chlorthal-Dimethyl (Dacthal, DCPA)	Metribuzin
Dimethanamid (Outlook)	Pronamide (Kerb)
Diuron (Karmex)	Simazine (Princep)

Herbicides Alphabetically Listed by Active Ingredient

* Federally restricted

bensulide (Prefar): preplant incorporated herbicide for control of various grass and certain broadleaf weeds in many vegetable crops.

bentazon (Basagran): postemergence herbicide in beans, peas and sweet corn for control of yellow nutsedge, smartweed and jimsonweed.

bromoxynil (Broclean, Maestro, and others): Note: some brands are registered in some states, and not others. For examples, Maestro is not registered in NH and VT while Broclean is registered in all New England states. Check state pesticide registrations before selecting a product to make sure it is legal to apply in your state. Used for postemergence control of broadleaf weeds when applied at the seedling stage. For use in garlic and onions.

carfentrazone (Aim): postemergence control of many broadleaf weeds in sweet corn, pumpkin, and winter squash.

clethodim (Select, Intensity): postemergence grass herbicide for use in many vegetable crops.

clomazone (Command): preemergence control of most grasses and some broadleaf weeds in pumpkins and peppers.

clopyralid (Stinger): postemergence herbicide for control of many annual and perennial broadleaf weeds in beets, sweet corn, spinach and turnip.

cycloate (Ro-Neet): preplant incorporated herbicide to control annual grasses, nutsedge, certain perennial grasses and many broadleaf weeds in beets and spinach. MA, NH and ME only.

DCPA (Dacthal): preemergence herbicide for control of annual grasses and certain annual broadleaf weeds in many vegetables. Restricted use in MA.

dicamba (Banvel, Clarity): postemergence herbicide in asparagus.

diquat (Diquat, Reglone): potato vine killer. Restricted use in NH and CT.

diuron (Karmex): preemergence herbicide controlling certain grasses and broadleaf weeds in asparagus beds.

EPTC (Eptam): for control of annual grassy weeds, nutgrass, perennial weeds such as Johnsongrass seedlings, quackgrass and several broadleaf weeds in beans (green) and potatoes. Restricted use in VT.

ethalfuralin (Curbit, Sonalan HFP): preemergence control of many annual grasses and broadleaf weeds in some vine crops (Cucurbit) and dry beans (Sonalan).

fluazifop (Fusilade DX): postemergence grass control herbicide for use on carrots, dry bulb onions, spinach and non-bearing asparagus.

flumioxazin (Chateau or Valor): preemergence and limited postemergence control of many broadleaf weeds and some grasses.

fomesafen (Reflex): pre- and postemergence weed control in beans and potatoes. Can only be used every-other year!

glyphosate (Roundup): many formulations available with varying % a.i. such as Roundup PowerMax, Roundup Pro, etc., in addition to many generic glyphosate products. A postemergence herbicide absorbed by the foliage of emerged annual and perennial weeds.

halosulfuron (Sandea): preemergence and postemergence herbicide for use in asparagus, beans, corn, cucurbits, and fruiting vegetables.

imazamox (Raptor): for early postemergence weed control in dry beans, lima beans, snap beans, and english peas.

linuron (Lorox): preemergence or postemergence herbicide for control of germinating and newly established broadleaf weeds and grasses in carrots and parsley. Restricted use in VT.

mesotrione (Callisto): pre- and postemergence control of many broadleaf weeds in sweet corn and asparagus. Generics are also now available.

metolachlor (Dual Magnum): preplant incorporated and preemergence weed control in corn, potato, pumpkin, and tomato. Restricted use in MA and VT.

metribuzin (Metribuzin): preemergence and early postemergence herbicide for control of a large number of grass and broadleaf weeds in potatoes and tomatoes. Restricted use in MA and VT.

napropamide (Devrinol): preplant incorporated herbicide for use in peppers, eggplant, tomatoes, asparagus and cole crops. For good control of barnyard grass, crabgrass, fall panicum, goosegrass, lambsquarter, pigweed and purslane. Photodegradable, must be incorporated within 24 hours by discing or watering in.

norflurazon (Solicam): preemergence used in asparagus.

oxyfluorfen (Goal): for control of certain annual grassy and broadleaf weeds in onions and crucifers.

***paraquat (Gramoxone Inteon 2S):** restricted-use pesticide. A contact "burndown" herbicide with no soil activity.

pelargonic acid (Scythe): postemergence contact herbicide for stale bed and directed/shielded applications in many vegetable crops.

pendimethalin (Prowl): preemergence herbicide for control of broadleaf weeds and grasses in asparagus, corn, peppers, potatoes, garlic, and onions. Restricted use in VT.

prometryn (Caparol): pre- and postemergence control of annual broadleaf weeds in carrots, celery, and parsley.

***pronamide (Kerb):** preemergence herbicide for weed control in lettuce.

quizalofop (Assure II): postemergence grass herbicide for use in beans and peas.

rimsulfuron (Matrix): preemergence and early postemergence herbicide for control of many grass and broadleaf weeds in potato. Restricted use in MA and VT.

sethoxydim (Poast): postemergence grass control herbicide for use in most vegetable crops. See label.

terbacil (Sinbar): preemergence and early postemergence herbicide for control of many broadleaf weeds in asparagus.

trifluralin (Treflan): preemergence herbicide that must be incorporated for control of many annual grasses and certain broadleaf weeds in many vegetable crops.

2,4-D (Amine 4): postemergence control of broadleaf weeds in asparagus and sweet corn. Restricted use in MA and VT.

Herbicides specific to corn

(not registered on other crops discussed in the New England Vegetable Management Guide)

***acetochlor (Harness, Surpas):** used for pre- and postemergence control of annual grasses and some broadleaf weeds in corn. Not registered for use in NH.

ametryn (Evik): used for postemergence weed control in field corn and popcorn. Not for use in ME, NH, or VT.

***atrazine (AAtrex):** provides season-long control of most broad-leaved weeds in sweet corn. Applied either preemergence, postemergence or in combination with other herbicides.

dimethenamid (Outlook): preemergence herbicide which provides grass and some broadleaf weed control in sweet corn.

fluthiacet-methyl (Cadet): Restricted use in some states. Not for use in fresh sweet corn. For use in field Corn, sweet corn grown for processing only, and popcorn.

nicosulfuron (Accent Q): postemergence grass herbicide in corn.

pyroxasulfone (Zidua): used pre- or early postemergence for weed control in corn. Not registered in VT.

safluenacil (Sharpen): used as a preplant surface, preplant incorporated, or preemergence to corn for broadleaf weed control. Not for use on sweet corn grown for fresh market use. Some corn varieties are sensitive to injury from this herbicide. Also used as a harvest aid for dry beans.

simazine (Princep): Restricted use in some states. Used preemergence before weeds and corn have emerged.

topramezone (Impact): postemergence control of many broadleaf weeds and some grasses in corn.

tembotrione (Laudis): postemergence herbicide for control of many broadleaf weeds in corn.

Note: Always check current registrations to be sure the herbicide is registered for the specific crop in question and state of use. Always read and follow all label instructions before using any pesticide!

Herbicides and Plastics

With the increased use of plastic culture for the production of various vegetable crops, it is very important to keep in mind a few points for proper weed management. Here are some tips:

- If methyl bromide or Vapam fumigation is used under the plastic strips, there is no need for a herbicide under the plastic. If soil fumigation is not used and black plastic is, it may not be necessary to put a herbicide under the plastic (unless nutsedge or other weeds are excessive). If you use clear or white plastic, without soil fumigation, then you need a herbicide under the plastic mulch. To get the best results, take the following steps for herbicide application:
- Prepare a pressed bed.

- Apply the herbicide to the bed surface.
- Activate the herbicide with rainfall or overhead irrigation (at least 1/2"); if the herbicide needs to be mechanically incorporated, do so and repress the bed.
- Apply the plastic mulch. Note: Some herbicides may volatilize and cause crop injury when used under plastic mulches or row covers. Some herbicides are prohibited from use under plastic. Be sure to observe any cautions on the product label. Wherever possible, try it on a small scale first.
- If weeds are present between the plastic strips before planting, use a banded application of Gramoxone plus surfactant, or Roundup (if registered for stale bed use) to kill all existing vegetation. Depending on the level of weed vigor, a second application of Gramoxone plus surfactant may be needed before planting. Do not broadcast apply these herbicides to the surface of the mulch.
- For weed control between the plastic strips, after planting, use a registered preemergence herbicide for that crop. Do not use nonregistered herbicides between strips as the crop roots will grow in that zone and, in many cases, the crop will be damaged or killed. Do not spray the surface of the plastic with any preemergence herbicides! During a rainfall the excess herbicide will wash into the holes where the crop was planted and will greatly concentrate the herbicide. Thus, the crop will be damaged or killed. When banded applications of herbicides are used, remember to adjust the rate of the herbicide downward to conform to the actual ground area being sprayed (with 30" beds and 30" areas between strips, only half the normal amount of herbicide would be required per acre since only half the amount of soil area per acre is actually being sprayed).
- Backpack sprayers or modified boom sprayers are often used for herbicide applications in plastic culture systems. Be sure to calibrate them properly and maintain a constant pressure using a pressure gauge, especially on hand-pumped models. Maintaining a constant speed or walking pace is also necessary. Three miles per hour is a good speed (23 seconds per 100').
- Use caution when spraying Gramoxone with a backpack or hand-held sprayer. Wear rubber boots, gloves and a mask or respirator. Avoid skin contact with the spray. If contact occurs, immediately rinse the area with water or rub soil on your skin. Soil will help soak up and bind the chemical, preventing its absorption into the skin. Spray when the wind is calm to avoid spray drift. Also, always use a surfactant and plenty of water with Gramoxone for good control.
- Vapam is not recommended for use in the spring if the plastic is to remain in place. Under the cool soil conditions at this time of year, the soil will not aerate properly and the crop will be damaged. In plastic culture, these materials are best used if the plastic is applied during the fall before planting. Be sure with all fumigants to space the injection shanks correctly. The label recommends a 6" spacing with Vapam.
- Herbicide use under row covers can be dangerous. Although several herbicides can be safely used under row

covers, some can cause crop injury and even crop death. Generally, ventilated covers are safer than solid covers or hot caps, from an herbicide injury standpoint. This is especially true with an herbicide that is moderately or highly volatile. Test on a small scale before you apply it on a large scale.

Stale Seedbed Technique

Certain weeds may be present in crop areas which herbicides and other management techniques cannot control well in the crop system. The stale seedbed technique can result in improved weed management in problematic areas or with problematic weed species. After soils are prepared for planting, most of the weed seeds in the upper 1-2" of the soil will germinate within two weeks if soil moisture and temperature are adequate. The stale seedbed approach involves preparing the soil as if for planting, without actually planting the crop. Instead, weeds are allowed, even encouraged (with irrigation or row covers), to grow. Weeds are then killed with Gramoxone, Roundup, Scythe or flaming.

Killing emerged weeds with herbicides or flaming does not disturb the soil, and no new weed seeds will be brought close to the soil surface. After using the stale seedbed technique, care should be taken not to disturb the soil any more than is absolutely necessary during the seeding or transplanting process to minimize the amount of weed seeds that are brought up to the surface to germinate. Preemergence herbicides can also be used after to increase the efficacy of stale seedbeds. Any cultivation performed after should be kept extremely shallow (3/4"-1" maximum) so as not to reposition any additional weed seeds.

On sandy, loamy or high organic matter soils, the soil should not crust and modern seeders should still work satisfactorily. On heavy clay soils, crusting could make this technique unusable.

Stale Seedbed Steps:

- Prepare the soil as if you are about to seed or transplant. If a soil-incorporated herbicide is used, it must be applied and incorporated at this time. The soil should have good moisture (irrigate with 1/4" of water if necessary).
- Wait as long as possible to allow weeds to germinate and emerge. Allow weed seedlings to grow to the third leaf stage, or at least to the first true leaf.
- If you're using transplants: flame the soil or make an application of Gramoxone, Scythe, Aim or Roundup (if registered for the crop) to the soil surface before transplanting. Transplant the crop (without dragging any additional soil off the bed) and then apply any preemergence herbicide, which you would normally use, to the soil surface.
- If the crop will be seeded: Gramoxone, Scythe, Aim or Roundup (if registered for the crop) or flaming may be applied just before or just after seeding (see the label). After seeding, apply any preemergence herbicide which you would normally use to the soil surface. CAUTION: If the crop has already been seeded, be careful that the flaming process does not injure the crop seed or the emerging crop seedling.

Table 27: Herbicides and Crops Registered

This is not a comprehensive list of all registered herbicides, but a reference of those more commonly used and registered in multiple crops. Please refer to individual crop sections for more information on herbicides.

Herbicide	Active Ingredient	Resistance Group ¹	Oral LD ₅₀	Asparagus	Beans, Dry and Lima	Beans, Pole and Snap	Brassicas**	Beets	Carrots	Celery	Cucurbits**	Corn, Sweet	Eggplant	Garlic	Lettuce	Onions**	Peas, green	Potatoes, Irish	Peppers	Pumpkins/Squash	Spinach	Tomatoes
Aim	carfentrazone	14	5,000+	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Assure II	quizalofop	1	5,900		R	R											R					
Basagran	bentazon	5	2,063		R	R						R					R					
Callisto	mesotrione	27	5,000+	R								R										
Caparol	prometryn	5	5,000+						R	R												
Chateau/Valor	flumioxazin	14	5,000+	R									R									
Command	clomazone	13	5,000+	R		R	R				R						R		R	R		
Curbit/Sonalan	ethalfuralin	3	5,000+		R						R									R		
Dacthal	DCPA	4	10,000+				R				R		R			R						R
Devrinol	napropamide	15	2,000+	R			R						R						R			R
Diquat	diquat	22	810																			
Dual Magnum	s-metolachlor	15	3,425	R^	R	R	R^	R^	R^		R^	R		R^		R^	R	R	R^	R	R^	R
Eptam	EPTC	8	1,325		R	R												R				
Fusilade	fluazifop	1	5,000+	R	R				R					R		R						
Goal	oxyfluorfen	14	5,000+											R		R						
Gramoxone Inteon*	paraquat	22	283	R	R	R	R		R		R	R	R	R	R	R	R	R	R	R		R
Karmex	diuron	7	2,900	R																		
Kerb*	pronamide	3	5,000+												R							
Lorox	linuron	7	4,833	R					R	R		R					R	R				
Matrix	rimsulfuron	2	5,000+															R				R
Metribuzin	metribuzin	5	2,375	R					R									R				R
Outlook	dimethenamid	15	2,400		R							R		R		R		R				
Poast	sethoxydim	1	4,100	R	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R	R	R
Prefar	bensulide	8	819				R			R	R		R	R	R	R			R	R		
Prowl	pendimethalin	3	3,956	R	R	R			R		R	R		R		R	R	R	R			
Ro-neet	cycloate	8	3,160					R														R
Roundup	glyphosate	9	5,000+	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Sandea	halosulfuron	2	1,287	R	R	R					R	R	R						R	R		R
Scythe	pelargonic acid	17	5,000+	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Select	clethodim	1	3,610	R	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R	R	R
Sinbar	terbacil	3	3,700	R																		
Solicam	norflurazon	12	1,140																			
Stinger	clopyralid	4	5,000+				R	R													R	
Treflan	trifluralin	3	3,700	R	R	R	R		R						R		R	R	R			R
2,4-D	2,4-D	4	1,161	R								R										

*Federally restricted **not all herbicides for use in all vegetables in this group, see crop section for details
¹Weed Science Society of America resistance code. ^ indemnified label available in some states
 R = registered for crop; check label to confirm state registration before using.

Table 28: Relative Effectiveness of Herbicides on Weed Species

Herbicide	Active Ingredient	Barnyard Grass	Crabgrass	Chickweed	Carpetweed	Fall Panicum	Fox Tail	Gainsoga	Johnsongrass (Rhizome)	Johnsongrass (Seedling)	Jimsonweed	Lambsquarter	Morning Glory	Mustard	Nightshade	Nutsedge yellow	Purslane	Pigweed	Quackgrass	Ragweed	Smartweed	Velvetleaf
Accent Q	nicosulfuron	E	P			E	E		P	E									P			
Aim	carfentrazone	P	P	P	G	P	P	G	P	P	G	E	E	P	G	P	G	E	P	F	G	E
Assure II	quizalofop	E	E	N	N	E	E	N	E	E	N	N	N	N	N	N	N	N	G	N	N	N
Atrazine*	atrazine	G	G	E	E	P	G	E	P	P	G	E	G	E	G	P	E	E	F	E	E	P
Basagran	bentazon	P	P	G	G	P	P	G	P	P	E	F	F	G	P	G	G	P	N	G	E	G
Callisto - pre	mesotrione	F	F	E	E	P	P	E	P	P	E	G	F	P	E	P	P	E	P	E	E	E
Callisto - post	mesotrione	F	F	E	E	P	P	E	P	P	E	G	F	E	E	F	P	E	P	F	E	E
Command	clomazone	G	G		N	G	G	F	N	F	F	G	P	N		N	G	P	N	F	F	E
Curbit	ethalfluralin	E	E	G	E	E	E	P	P	E	P	F	P		G	P	E	E		F	F	F
Dacthal	DCPA	F	E	G	G	F	E	P	P	G	P	E	P	N	P	P	G	E	P	P	P	P
Devrinol	napropamide	G	E	E	G	G	E	G	P	P	P	F	P	P	P	P	G	G	P	G	F	P
Dual	metolachlor	G	E	G	G	E	E	E	P	F	P	F	P	P	G	G	E	G	P	F	F	P
Eptam	EPTC	G	E	F	G	G	E	F	P	G	P	G	P	P	P	G	G	G	F	P	P	E
Fusilade	fluazifop	E	E	N	N	E	E	N	N	E	N	N	N	N	N	N	N	N	G	N	N	N
Goal	oxyflouren	F	F	E	E	F	F	G	P	F	F	E	P		E	P	E	E		E	E	F
Gramoxone	paraquat	E	E	G	E	E	E	G	P	F	G	E	G	G	G	P	G	E	F	E	G	G
Impact	topramezone	F	F	E	E	F	P	E	P	P	E	G	F	P	E	P	P	E	P	E	E	E
Karmex	diuron	G	G	G	G	F	G	G	P	P	G	E	F	G	G	P	E	E	P	G	F	F
Kerb*	pronamide	G	G		G	G	G	P	P	G	P	G					G	G		P		P
Laudis	tembotrione	F	F	E	E	P	P	E	P	P	E	G	F	E	E	F	P	E	P	F	E	E
Lorox	linurin	E	E	G	E	E	E	G	P	G	E	G	G	E	G	G	G	G	P	G	G	G
Matrix	rimsulfuron	E	P			G	E	G			F	F	F	G	F	P	G	E	G	P	P	P
Metribuzin-pre	metribuzin	G	G	G	E	E	E	E	P	F	E	E	F	E	P	P	E	E	N	G	G	G
Metribuzin-post	metribuzin	G	G	G	E	E	E	E	P	F	E	E	F	E	P	E	E	E	P	G	G	G
Outlook	dimetheramid	E	E			E	E	E				P		P	G	G	F	F	P	P	F	P
Poast	sethoxydim	E	E	N	N	E	E	N	E	E	N	N	N	N	N	N	N	N	G	N	N	N
Prefar	bensulide	E	E	P	P	E	E	P	P	P	N	P	P	N	P	P	P	P	N	P	P	P
Princep	simazine	E	G	E	E	G	G	E	P	P	E	E	G	E	G	P	E	E	F	E	E	G
Prowl	pendimethalin	G	E	G	G	G	E	P	P	G	P	G	P		P	P	G	G		P	P	E
Ro-neet	cycloate	E	E			E	E	P				E		N	E	G	E	E	N	N		F
Roundup	glyphosate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E	G	E	E	E
Sandea	halosulfuron	P	P			P	P		P	P		F	F	G		G		E	P	E	E	E
Scythe	pelargonic acid	E	E	G	E	E	E	G	P	F	G	E	G	G	G	P	G	E	F	E	G	G
Select	clethodim	E	E	N	N	E	E	N	E	E	N	N	N	N	N	N	N	N	G	N	N	N
Stinger	clopyralid	N	N		N	N	N	G	N	N	P	P	N				N	N	N	G	P	P
Treflan	trifluralin	G	E	E	G	G	E	P	F	G	P	G	P	P	P	P	G	G	P	F	P	P
2,4-D	2,4-D	N	N	G	G	N	N	G	N	N	E	E	G	G	E	F	G	E	N	E	F	G
Zidua	pyroxasulfone	G	E	G	G	E	E	E	P	F	P	G	P	P	G	F	E	E	P	G	F	P

*Federally restricted herbicide
 At recommended rates for your soil type or weed species: E=90% control or better, G=70%-90% control, F=50%-70% control, P=5%-50% control, N=less than 5% control

Check the current herbicide label and recommendations by crop to determine if Gramoxone, Scythe, Aim or Roundup is registered for use in that crop. Gramoxone, Scythe, Aim and flaming will have minimal long-term effect on established perennial weeds. For cucumbers, melons, squash, pumpkin, peppers and eggplant, Roundup must be applied at least three days prior to seeding or transplanting.

In cases where Roundup is registered, it can also be used for control of perennial weeds, such as quackgrass and dock, prior to soil preparation. After application, delay tillage for three to five days. There is no residual weed control. See the label for directions.

VERTEBRATE PEST MANAGEMENT

USDA Wildlife Services staff are available to assist with a variety of wildlife damage issues, including voles. Their telephone number for **New Hampshire & Vermont** growers is (603) 223-6832. For growers in **Connecticut, Massachusetts** and **Rhode Island**: (413) 253-2403. For **Maine**: (207) 629-5181. The website is http://www.aphis.usda.gov/wildlife_damage. Trapping is often highly regulated; laws are restrictive and may be complex. Environmental Police Officers enforce trapping laws. Know the current laws and regulations before trapping any wildlife. Reductions in animal numbers by lethal methods fail to provide a long-term solution from wildlife damage in the absence of habitat modifications and exclusion methods. Most nuisance wildlife will repopulate areas soon after control efforts have ceased. Habitat modification and exclusion methods often require more expense and initial effort, but these methods will result in more durable damage prevention.

Deer

White-tailed deer are common in New England, and sweet potato leaves and vines are among their most preferred foods. In some areas, they heavily attack pumpkins, both the plants and fruit. We also see damage to butternut squash, lettuce, and occasionally tomato and other vegetable plants. They are very active at night, but during the summer they are almost as active during the day.

Fencing: Permanent mesh fencing can keep them out if it is 8-10 feet high. Such fencing restricts vehicle movement, so carefully consider turning distances, entrance locations and gate width before making an investment in permanent fencing. Temporary electric fencing is relatively inexpensive and simple to set up. It can work very well if you bait it immediately after erecting it. Even a single electric strand at 36-40 inches can work if the deer have other feeding options. White electric tape is especially visible and works well in this application. The most common method to bait an electric fence for deer is to apply peanut butter to strips of aluminum foil and fold them (sticky side in) over the fence at about a 40-inch height, at intervals of about 30-50 feet. By licking the tasty treat they can smell, deer quickly learn that the fence can hurt them, and they keep away. Usually, the baits do not need replenishing if they are used for less than one growing season.

Repellents for deer are designed to work by odor or taste. Most commercial products are not labeled for use on vegetable crops.

Shooting is one option that growers may consider, but the rules vary greatly from state to state. Sometimes officials will readily give out permits to shoot offending deer. Shooting is not as effective as fencing and brings on issues of safety, neighbors, and farmer image. Deer are protected species in all New England states, so check with state Fish and Game authorities or USDA Wildlife Services staff before shooting. Shooting also has safety issues.

Birds

Most birds in New England that are pests of vegetables are species with either partial or complete legal protection. State, federal and international laws/treaties are involved in their protection. This limits some of our management options. Crows and ravens often pull out seedling corn plants, to reach and consume the seed. They, along with blackbirds and starlings, frequently attack milk stage corn, especially in varieties where the ears are not well covered by the husks. Turkeys feed on kale, collards, lettuce, and mesclun mix. They also peck both green and ripe tomato fruit. Canada geese like to eat grasses and winter rye, sometimes corn. Occasionally birds cause losses by defecating on the crops. This is most common when open containers of product are placed in an open shed or barn, where English sparrows can perch in the rafters above. In that situation, growers can install netting to exclude birds from the rafter area. Canada geese defecating while grazing on grassy weeds can be an issue on low crops that are eaten fresh, like lettuce and spinach.

There are a variety of devices designed to manage bird problems. Netting is one possibility but is most appropriate for high-value perennial crops, not most vegetables. Some of the insect and hail netting designed to protect mesclun mix and other low crops can be supported by wire hoops and stops turkey feeding.

Taste repellents: Some taste repellents are available (methyl anthranilate for example) on some crops, but they are applicable to few vegetable crops and have variable results in our area. An exception is 9,10-anthraquinone, sold as Avipel. It is registered (effective) as a seed treatment on corn to keep birds from walking down the rows and pulling out the seedlings. Currently it is registered in Maine, Vermont, New Hampshire and Massachusetts.

In states where anthraquinone is not registered, growers have used two methods to reduce seedling pulling by crows and ravens. One method is to set up tomato stakes in a zig-zag pattern, on a recently planted sweet corn field. Attach fishing line to the stakes. This seems to deter crows from landing. When the seedlings are large enough that the birds can't pull them out, you can reel up the fishing line, retrieve the stakes and put them in your next planting. Another alternative is to plant sweet corn into a (low) standing stubble. It can make the young plants harder for the crows to spot.

Scare devices can be relatively effective, especially on flocking species. All birds become habituated to scary noises, especially if they are used alone and constantly. Therefore, incorporating variability and change (sound, location, etc) is important to being successful with scare devices. Bird Damage Prevention For Northern New England Fruit Growers covers most scare devices. Two relatively new ones not covered in that publication are Air Crow and laser lights. Air crow is a colored nylon tube/scarecrow attached to a

blower. When in use, it moves constantly and can be quickly turned off when not in use. Set it in a location that makes it visible. For tall crops, that might be on a bin or stand. As with other scare devices, it is most effective when combined with other methods. A Canadian company called *Carpe diem* has been selling a system of laser lights mounted on a firm mast. Some New England vegetable growers have been very happy with the results scaring various birds, despite the high cost (\$2500 or more).

Auditory bird scare devices can be fairly effective, especially if the noises they create are varied. Automated propane cannons can be effective for a relatively short time, but are very annoying to neighbors, customers, and farm workers. In New England, automatic cannons have been the source of several serious disputes with neighbors. Screamers and bangers are auditory devices that are fired from a launcher (looks like a plastic handgun). They can cost \$2.50 or more per shot but can be helpful occasionally to move out a flock of birds. Regulations cover the purchase and use of these devices. Be sure to check local regulations about their use before you begin.

Silhouettes of coyotes or other predators don't work very well to scare birds (or other vertebrate pests of vegetables). Effigies are slightly more effective, especially those that employ movement. They are still more effective if you regularly move them to different spots. If you combine them with auditory scare devices, the effectiveness usually goes up.

Some growers employ scare-eye balloons to protect sweet corn from pecking. Growers report that the light colored balloons work better than the dark ones. There are some larger ones with "holographic" eyes that seem to follow you as you walk by. Growers have had relatively good results with them. With all of the balloons, it is important to suspend them from high poles 2-5 feet above the crop.

Shooting is rarely successful at controlling bird problems. The main effect is scaring away the survivors. There are local, state and international laws that affect if, where and how shooting may be employed.

Rodents

Rodents are distinguishable by their teeth. They have sharp, opposing incisors plus strong molars to grind up material. Between the incisors and molars, there is a broad gap with no teeth.

Woodchucks

Woodchucks especially like to eat beans, peas, carrot greens, alfalfa, clover, and grasses. They also eat cabbage, broccoli, tomato, dandelion, and other plants. There are few succulent plants that they won't eat. They don't seem to prefer corn. They are most active early in the morning and late in the afternoon. They dig extensive burrows that are used as escape cover, shelter, or overwintering sites by many other animals. Cottontail rabbits, skunks, raccoons, foxes, coyotes, snakes, weasels, and chipmunks are among the animals that use woodchuck burrows. Woodchucks are also prey for foxes and coyotes, bobcats, fishers, eagles, and large hawks. Please consider these points before jumping to lethal control measures for woodchucks. Both lethal and non-lethal control options are available.

Non-lethal measures: Frightening devices don't seem to be effective to deter woodchuck feeding. Although some taste repellents are available, they are not very practical for vegetable crops that people will be eating. Fencing can be very effective but restricts vehicle movement. Also, if you depend on fencing, be sure the woodchuck burrow is not inside the fence. Since woodchucks can climb and burrow, the most effective alternative is electric fencing. An effective combination is one wire 4 inches off the ground and a second at 8 or 9 inches high. Dealers offer a wide variety of plug-in and battery powered, UL-approved chargers. Keep the fence clear of any obstructions or vegetation that might short out the electric pulses.

If you use non-electric fencing, buy a mesh size smaller than 2 x 2 inches, especially close to the ground. (The young ones can sometimes squeeze through that mesh size.) Common chicken wire rusts away quickly—the woodchucks may push through it by the second growing season. Non-electric fencing should have some means of preventing the woodchucks from burrowing underneath. You could bury the fence to a depth of 10 or 12 inches. Or you could bend the lower 1 foot 90 degrees outward, to form an "L", then lay it on the ground and securely pin the L into the ground. Another option is laying an 18-inch wide strip of galvanized fencing on the ground below the fence, and keep the vertical fence flush with it. Non-electric fences need to be at least 3 feet high. Bending the top 12-15 inches outward at about a 45-degree angle will help deter them from climbing a non-electrified fence. Don't neglect the gate. That is often the spot where defenses are the weakest. If animals try to burrow underneath, install a board dug into the ground and flush with the bottom of the gate, or lay down a length of fencing as described above.

Live trapping is a possibility in some situations, but it carries risks. Small details in setup make big differences in the success rate. If a carrier of rabies were trapped, handling it could be a risk to any non-vaccinated person who was exposed. Trapping and translocating a woodchuck from its home is subjecting the "humanely trapped" animal to a prolonged, very stressful ordeal that often ends in its death. Suitable habitat is farmland with open fields and an abundance of short grasses. Farmers or gardeners are not likely to agree to your releasing animals on their property, and woodchucks are not woodland creatures. In some New England states, laws prohibit the practice of transporting and releasing trapped animals.

The most effective technique is to place the trap directly at the burrow entrance and use a barrier of boards or other material to direct the animal into the trap as it leaves its burrow. No bait is needed in this situation. Trap placement elsewhere is much less effective, but sometimes the woodchuck can be enticed inside with fresh apple slices or fresh carrots or lettuce. Change baits daily.

Lethal controls: use them cautiously, after careful thought. They can end up killing non-target animals. Gas cartridges are cardboard cylinders filled with slow-burning, asphyxiating chemicals. Locate an active burrow, and treat when you are sure the woodchuck is inside. Find and close all but one entrance, and prepare a sod plug for the opening. Attach the cartridge to a 3-foot branch, light the fuse, and place it well inside. Immediately seal the entrance. Most

failures with cartridges are from the fuses going out (often because loose dirt covered them, or they were thrown). Sometimes they fail because the woodchuck was somewhere else when the burrow was fumigated. Upon its return, it just re-opens the burrow. Never use a gas cartridge near flammables or under a wooden structure.

Conibear traps are body-gripping steel traps that almost instantly kill an animal that tries to move through. If a pet or other non-target animal walks through one, there is no second chance. Use these traps only where you are certain the intended target is the only animal that can enter. They are usually placed just inside the burrow, to trap the occupant as it enters or leaves. Conibear sizes 160 and 220 are appropriate sizes for woodchucks. This risky method requires permits or licenses in many areas, so check first before using this.

Shooting is an option that has a low risk of harming non-target animals if done carefully. In many New England states, woodchucks can be shot by anyone with a hunting license, or by farmers on their own property, protecting their crops. In most New England states, there is no closed season on woodchucks. A .22 caliber rifle with hollow point cartridge is the most commonly employed weapon for woodchuck control. When shooting, take extreme care that the area is safe for a shot. A .22 caliber long rifle bullet can travel nearly a mile if it does not strike something first. They easily ricochet off hard surfaces.

Voles

Voles can attack a wide range of plants. In New England, they have been reported attacking tomato, asparagus, potato, sweet potato, carrot and other vegetables. Grasses are especially favored food for several species of voles. We have four vole species [meadow, southern redback, rock, pine] that can cause problems in New England, but most suspicion falls on meadow voles and pine voles. Pine voles primarily live and feed in tunnels underground, and readily attack root crops: carrot, beet, potato and sweet potato. They have very short tails, never longer than their hind feet. Meadow voles largely live above-ground and have tails that are longer than their hind feet. Voles have less prominent eyes than mice, and their ears are buried in the fur. Mice have prominent ears.

We have few options to manage pine voles on vegetable farms. Problems are most common in soils that are adjacent to woodlands or orchards. Soils that are poor for pine voles are those that are commonly waterlogged, or have very high clay content, or are almost entirely sand. Tunneling is difficult in those conditions. Meadow voles mostly live above ground and often chew off plants just above the soil line, especially if there is a lot of vegetation to hide them. Weedy fields and field edges are common sites of attack. Sometimes voles attack when very young plants are still in liner or plug trays on the ground in a high tunnel. Meadow voles have an extremely high reproduction rate, so their populations can rebound rapidly after controls are implemented.

Voles prefer areas with good cover, so maintaining good weed control is important to reduce the risk of vole problems. Piles of debris placed right next to high-risk crops (like a high tunnel full of transplants) are invitations for vole problems. If you use a mulch, it can encourage vole problems.

This includes organic materials like grass clippings, woven blankets, or extruded materials like plastic.

Rodenticides: There are rodenticides registered for use against voles in orchards, fruit groves, nurseries, and highbush blueberries. Currently, there are no rodenticides registered for use in vegetable fields. A limited number of products might be legal for use (gray zone) in high tunnels and in and immediately around other buildings, but they may be of very limited use. There are quite a few rodent baits registered for commensal (in and around buildings) rodent control, but the term vole rarely appears on their labels. For the most part, commensal rodent control products are intended for mice and rats, and the bait is formulated to appeal to those species, not voles.

Be very cautious about using the second-generation anticoagulants (brodifacoum, difethialone, bromadiolone). These materials (esp. brodifacoum) have been found in an amazingly high percentage of dead, sick or injured predatory birds and predatory mammals in the northeast states. EPA responded to this problem by drastically reducing the availability of brodifacoum products for use by non-licensed applicators. But it is still available for licensed applicators, in and around buildings. If pets or wildlife can reach the bait, they can be poisoned.

In most cases, the rodenticide labels state that rodent baits must be used in bait stations. In part, this is to reduce the risk of direct poisoning to domestic animals. But secondary poisoning can occur (brodifacoum for example), where one animal eats the bait and becomes weakened or dies. Then a second animal eats the target pest and becomes a victim.

Rodenticide labels are usually available to examine at the manufacturer's website. Common manufacturers that include some field-applied products registered in New England include:

- Bell labs <http://www.belllabs.com/>
- Bonide <https://www.bonide.com/>
- HACCO <http://www.hacco.com/Rodenticides.htm>
- Liphatech <http://www.liphatech.com/>

There are many additional manufacturers that provide materials for commensal (in and around homes) rodent control. If you cannot tell if a rodenticide is registered for use in your state, check the registration list. Each New England state has a list of pesticides that are registered in that state for that year. Often the list is incomplete early in the year. In most states, that list is available through the state pesticide control division.

Trapping is a possibility for meadow, redback and rock voles, but it isn't very practical. Tiny details have a major effect on trapping success. In a situation where high-value plants are concentrated and damage is significant (high tunnel full of plugs or transplants for example) careful trapping might help. In that case, one or more vole tubes might be a good situation for a trap. Using scrap lumber, you create a 16-18 inch long narrow tube, whose rectangular interior dimensions fit a standard mousetrap, leaving enough room for the spring bar to clear the ceiling. For most traps, that inside measurement would be 2" wide and 2.5" high. At the center of one side, leave an opening large enough to easily insert a mouse trap. Consider placing two traps in a

tube, each one with the trigger facing its respective end. Then gently set the tube in the desired location and place a piece of cardboard to cover the side opening. No bait is needed. Voles like traveling in protected runs and this catches them as they try to use an inviting runway. It keeps the trap safe from your cat or dog, and your workers' toes. One spot to place a tube is where there is an established path between the trays of plug plants.

Vole Problems in High Tunnels/Greenhouses

Growing vegetables inside structures presents a different set of regulations, compared to outdoors. The use of rodenticides is one area that is not very clearly defined in this situation. Many rodenticides are labeled for "commensal" (means in and around buildings) rodent control, not for use on or around a crop. When you grow a crop inside the structure, that brings up new legality issues. Also, commensal rodenticides are typically formulated to entice rats and mice, not voles. Cats find warm greenhouses and high tunnels especially inviting, and this behavior increases the risk of poisoning them if you use rodenticides in or around those structures. As described above, secondary poisoning is a significant concern with some rodenticides.

For a greenhouse in which you plan to grow vegetables, it is possible to reduce the chances of having vole problems by using ¼ inch mesh hardware cloth to seal all openings at or near ground level. Bury the edges well. High tunnels are much harder to protect from vole entry. In both high tunnels and greenhouses, control weeds well inside. Just outside, keep the vegetation well mowed or controlled with herbicides.

Other Rodents

Gray Squirrels commonly raid ears of corn, especially if they are close to woods. Damage is sporadic, so usually, controls are not warranted. Gray squirrels are protected species in all New England states.

Mice tend to be seed eaters, though some will feed on fruits when given an opportunity. The white-footed mouse is a common New England species that frequently moves into buildings, especially in fall and winter. Usually, we do not see evidence of them attacking vegetable plants. Mice have prominent ears and eyes, while voles tend to have smaller ears and less prominent eyes.

Muskrats are rodents that are strongly associated with ponds, marshes or slow rivers. They eat aquatic plants, but occasionally attack corn, beans, wheat or oats that are growing adjacent to wetlands. Attack is uncommon, so it rarely warrants control.

Rats (Norway, roof) occasionally attack picked vegetables stored in containers indoors, but rarely are reported attacking the plants in the field. Rat control can be very demanding. It requires eliminating food sources, plugging holes in walls, and careful use of traps and/or rodenticides. Rats are notoriously reluctant to try new foods (like rodent baits), and resistance to rodenticides is a problem. Rat control in buildings isn't the focus of this reference, so you'll need to look elsewhere for details.

Lagomorphs (Rabbits and Hares)

Rabbits and hares are close relatives of rodents. Cottontails are the most common species attacking vegetables. We have

two species here: New England cottontail and the larger Eastern cottontail. They eat a wide variety of vegetable plants [carrot, pea, bean, beets, lettuce, spinach and others]. They do not tend to feed on corn, squash, tomato, cucumber, potato. They eat many flowers (tulips for example). Good cover is especially important to help hide these animals from their many enemies. Western Connecticut has European hare, and northern New England has varying (snowshoe) hare, but these are not usually associated with damage to vegetables.

We most commonly use fencing for lagomorph control. Two-foot high fence with 1-inch mesh is sufficient if it is buried slightly into the ground. Chicken wire can work, but very young rabbits can sometimes squeeze through. Electric fencing designed for woodchucks or raccoons is often effective and less expensive than erecting mesh fencing.

Thiram is fungicide that is a taste repellent that works on rabbits, but it is not labeled for use on vegetables. Shooting may be an option in some situations, but these are protected species, so be sure to check first on state regulations. There are safety issues with shooting. We most commonly use a .22 rimfire rifle for rabbit control.

Rabbits strongly prefer to be in thick cover, so good weed control and mowing edges can help reduce the risk of damage.

Carnivores

Raccoons

Raccoons are a common animal that are especially active at night. Before the raccoon strain of rabies moved through New England (mid 1990's), raccoon damage to sweet corn was a very serious problem, and many growers used electric fences to protect sweet corn in the milk stage. Today sweet corn damage from raccoons is less common. Raccoons also attack cantaloupe and watermelon fruits. They are most active at night.

Fencing: The most common and effective control for raccoons is using electric fences, with one wire at 6-inch height and a second at 12 inches. Sometimes a single wire at 6 inches works well. Be certain that vegetation is cleared from the fence, or it will reduce the shock an animal receives when it contacts the wire. Fencing will limit vehicular traffic, but temporary clip-on gates are easy to install.

Trapping: Some farmers employ trapping, but it can be difficult and time-consuming to do properly and may be subject to local and/or state laws. The raccoon is a protected species, and the rules vary state to state. Live trapping requires a sturdy trap and an effective bait. Sardines are one bait that has worked. Transporting trapped animals is illegal in some New England states. Conibear (lethal body-gripping) traps can work but must be placed in a spot where pets cannot get to them. They do pose a risk to other wildlife, as well as pets and people. An animal that steps into one does not get a second chance. Leghold traps can be effective, but it is tricky to set them properly, they pose a risk to pets, wildlife, and possibly people. If you do use traps and need to move a dead raccoon, be careful to use rubber gloves. Raccoons can harbor the nematode *Baylisascaris procyonis* ("raccoon roundworm") that can parasitize people. Raccoons can be infected with rabies virus, which is lethal to people.

Other Carnivores

Opossum occasionally feeds on sweet corn, and some fruits. It is an omnivore that feeds on carrion, and also eats fruits & grains. It is more active at night than by day. Electric fencing is the most appropriate control method.

Red fox is common in New England and sometimes feeds on ears of corn or cantaloupe fruits. We rarely get reports of significant damage. Foxes are valuable predators of voles and other pests, so we generally consider their presence beneficial. They are protected in all New England states.

Black bears are more common in northern New England than southern New England. Bears readily attack sweet corn and field corn in the milk stage. Damage often occurs in large spots in the middle of the field, where the bears pull down all of the stalks and are hidden from view. Since black bears are protected by laws, contact your state Fish & Game officials or USDA Wildlife Services staff for assistance if you have a bear problem.

Resources

USDA Wildlife Services staff are available to assist with a variety of wildlife damage issues, including voles. Their telephone number for New Hampshire & Vermont growers is (603) 223-6832. For growers in Connecticut, Massachusetts and Rhode Island: (413) 253-2403. For Maine: (207) 629-5181. The website is http://www.aphis.usda.gov/wildlife_damage/

Bird Damage Prevention For Northern New England Fruit Growers https://extension.unh.edu/resources/files/Resource001797_Rep2514.pdf

Dealing With Woodchuck Damage https://extension.unh.edu/resources/files/Resource000562_Rep584.pdf

Managing Voles in New Hampshire Orchards and Highbush Blueberries https://extension.unh.edu/resources/files/Resource003424_Rep4893.pdf

Carpe diem technologies www.carpediemtechnologies.com offers laser bird scare devices.

Orchard Equipment Supply Company (OESCO), Conway, MA. www.oescoinc.com. 1-800-634-5557.

Wellscoft Fence Systems Chesham, NH. www.wellscoft.com 1-855-327-6336.

Crops Varieties, Care, and Control

ASPARAGUS

Asparagus (*Asparagus officinalis*) is a perennial crop in the lily family. It originated near the Mediterranean and has been used as an agricultural crop since the time of the ancient Greeks. Asparagus beds usually produce well for 10-15 years, so choose a site with that in mind. Avoid areas where this tall crop could shade other crops. Select soils that are deep and well drained, such as sandy loams or well-drained loams. However, the water table should not be more than four feet below the surface. The site should not have been planted with asparagus for a long period, preferably never for this crop. This is to minimize asparagus crown rot (*Fusarium moniliforme*) which can survive for a long time in the soil even without a host. Land cropped to corn within 3 years should also be avoided since some strains of *F. moniliforme* can also infect corn. Avoid areas subject to late spring frosts as emerging spears are easily injured. Site preparation should begin at least 1 year prior to planting in order to properly adjust soil pH, fertility, and eliminate serious perennial weed problems.

Types and Varieties

All-male hybrids that are tolerant to crown or root rot caused by *Fusarium* species should be grown. The varieties listed here are tolerant to *Fusarium* and to rust. The “Jersey” series are generally all-male hybrids. (Older varieties were half male and half female plants.) Mary Washington and some other old varieties are still available, but are highly susceptible to crown rot and are less productive than all-male hybrids. Male plants do not expend energy producing seed and are thus more vigorous than female plants. Also, the lack of seed precludes the growth of nuisance seedlings which are not productive and act as weeds.

Asparagus Varieties				
Jersey Giant*	Jersey Supreme	Jersey Knight	Millennium	Purple Passion (purple)
*Some plants are female.				

Soil Fertility

The year before planting, adjust the pH and build fertility in the soil based on soil testing results (see Table below). Asparagus does not tolerate acid soils. Apply lime to maintain soil pH at 6.8-7.0. This may require yearly applications of lime. For new beds, deeply incorporate lime to ensure proper pH at crown depth.

Asparagus is planted fairly deeply and the roots are known to penetrate deeper than 6 feet. Since there is little downward movement of phosphorus in the soil, it is important to get phosphorus into the root zone before planting. Till deeply and mix fertilizer material well into the deep root zone.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15). The second year after planting, the asparagus should receive fertilizer in the early spring and late summer. In subsequent years the bed should be fertilized after each harvest season. Base fertilizer rates on soil test results.

Asparagus has moderate requirements for boron. For soils low in boron, apply 1-2 lbs per acre of actual boron every 3 years to asparagus plantings.

Planting

Crowns: Plant healthy one-year-old crowns in raised beds at the bottom of 8-inch deep furrows. Be sure the bud is facing

Plant Nutrient Recommendation According to Soil Test Results for Asparagus

ASPARAGUS	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
New Asparagus Beds:									
Broadcast and Incorporate	50	150	90	30	0	200	150	75	0
In Bottom of Furrow at Planting	0	30	30	30	30	0	0	0	0
TOTAL RECOMMENDED	50	180	120	60	30	200	150	75	0
Established Hybrid Asparagus Beds:									
Broadcast after Cutting Season	75	150	90	30-60	0	300	150	75	0
TOTAL RECOMMENDED	75	150	90	30-60	0	300	150	75	0
Established Non-Hybrid Asparagus Beds:									
Broadcast after Cutting Season	50	150	90	30-60	0	200	100	50	0
TOTAL RECOMMENDED	50	150	90	30-60	0	200	100	50	0

up and roots are spread out. Space crowns 12" apart in rows 54"-60" apart. Closer spacing produces higher yields in early years, but thinner spears in older beds. This will require 8,712-9,680 crowns per acre or 100 crowns per 100 feet of row. This spacing is for hybrids and is somewhat greater than was recommended for less vigorous non-hybrids. Cover with 2" of soil, and during the rest of the season the furrow should be filled in bit by bit being careful not to cover the asparagus foliage.

Transplants: Fields can also be planted with 8- to 12-week-old asparagus seedlings after the danger of frost has passed. Plant spacing is the same as for crowns. Care must be taken in order to prevent the small young ferns from being smothered by soil especially after heavy spring showers. To accommodate the growth pattern of asparagus roots use trays with straight, non-foam, non-tapering cells measuring 2 x 2 x 3 inches. Use a sterilized medium consisting of half sand and half peat or use a commercial seed starting mix. Seed germination will take at least three weeks and the soil must be kept uniformly moist during this time. Young seedlings should be fed with quarter- or half-strength soluble fertilizer solution once each week or as needed. The nitrogen in this fertilizer should be in the nitrate form because young seedlings are sensitive to ammonium sources of nitrogen. The seedlings should be grown in the greenhouse for 6-8 weeks followed by 2 weeks of hardening off, prior to planting after the danger of frost has passed.

Field Culture

It is essential to maintain healthy fern growth during the first two growing seasons. Weed control is easily accomplished by slowly filling in the trenches over the course of the first season. These cultivations can be timed with flushes of weeds. Be sure ferns are not covered. During the second year the beds must be kept weed free, especially during late summer and fall. Weed competition late in the season will restrict crown growth. Close attention must be given to insects and diseases that attack young ferns. As ferns become vigorous and full, diseases can cause the ferns to die prematurely, especially in late summer and early fall during periods of humid weather. Fungicides should be applied to control this foliage decline.

Mow brush in early spring before spear emergence followed by shallow discing, no deeper than 2"-3" in order to prevent crown injury. Some growers remove ferns in the late fall or burn the ferns during the winter. This can destroy rust and purple spot inoculum and reduce harboring sites for insects. Beds can also be disced immediately after harvest to control weeds prior to herbicide application.

Harvest and Storage

Spears may be harvested two times at the beginning of the second season. The harvest season is increased one to two weeks in subsequent years and should be six to eight weeks in mature beds depending on plant health during the previous summer and fall. If spears are predominantly small in diameter, harvest should be stopped. Overcutting causes rapid decline in bed vigor. Spears can be snapped or cut at or below the soil surface. Avoid injury to newly emerging spears.

Once spears have been bunched and trimmed, they should be placed upright in shallow trays of water and kept cool.

Ideally they should be refrigerated at 32°F in order to maintain sugar content and tenderness.

Mother Stalk Harvest Method: (trial only) In Japan and China, harvest throughout the summer is common. In this method, spring harvest is carried out for two weeks, after which three or four strong spears are left to grow into full ferns. From this point, newly emerging spears can be harvested throughout the season into early fall. Spear production is influenced by soil temperature and nutrient availability. Fertigation is usually practiced with this method. Plants have been shown to have similar longevity as those harvested in the spring only.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Crown Rot (*Fusarium* species)

Vigorously growing plants are less susceptible to crown rot. Buy top quality crowns. Use new land or land where asparagus has not been grown for 10 years. Use tolerant varieties.

■ Rust (*Puccinia asparagi*)

Rust disease attacks fern foliage and can spread rapidly affecting production in subsequent years. Fern residues should be removed and destroyed prior to spear emergence in the spring. Control volunteer asparagus plants that might be infected. Resistant cultivars are not available. Apply fungicides after spear harvest is complete.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

chlorothalonil (Bravo Weather Stik): 2.0 to 4.0 pt/A; PHI 190d, REI 12h, Group M5. Do not apply within 190 days of the harvest of spears in the following season.

mancozeb (Dithane F45): 1.6 qt/A; PHI 180d, REI 24h, Group M3. Begin applications after spears have been harvested.

myclobutanil (Rally): 5.0 oz/A; PHI 180d, REI 24h, Group 3. Begin applications after spears have been harvested. Observe a 30-day plant-back interval between the last application and planting new crops at the treatment site.

sulfur (Microthiol Dispers^{OG}): 10 to 20 lb/A; PHI 0d, REI 24h, Group M2. Apply to ferns after cutting.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special

instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Asparagus Aphids (*Brachycorynella asparagi*)

Asparagus aphids are small (1.6 to 2 mm), oval, green to gray aphids that may be covered in a waxy secretion. They overwinter as eggs on asparagus residue in the field. Eggs hatch in spring and nymphs and adults feed on spears, then on ferns. During the summer, wingless females produce live young (nymphs) which develop into reproductive females in 8-10 days. Populations can build up rapidly especially in hot, dry weather. Aphids feed on new growth and cause shortening of internodes, rosetting, or 'witches broom' appearance of the foliage. High aphid populations reduce root growth and plant vigor and may kill seedlings. Younger plantings are most vulnerable, especially 2- or 3-year-old plantings that are not being harvested. Cold winters and aphid infestation have a synergistic effect on plant health, greater than either factor alone. Asparagus can also vector viruses, including asparagus virus I and II (AV-I and AV-II) and tobacco streak virus (TSV). During harvest, monitor any plantings that are not being harvested. After harvest, scout ferns for signs of feeding injury and aphid colonies, especially in the basal regions of the plant. Cultural controls include harvesting spears in spring, because only volunteer plants and young plantings that are not harvested will allow aphids to survive and multiply. Remove dead ferns during the fall or winter, and control between-row volunteers through spring tillage or herbicides. Natural biocontrol is provided by insect predators such as lady beetles, lacewings, predatory midges, and flower fly larvae, by the parasitic Braconid wasp, *Diaeretiella rapea*, and by a fungal pathogen that is more active in humid climates. Treat ferns when populations are low, if 5% of ferns show injury. Conserve beneficials by using a selective product. Scout again in 5-7 days to determine if further treatment is needed.

acetamiprid (Assail 30SG): 2.5 to 5.3 oz/A; PHI 1d, REI 12h, Bee: M, Group 4A.

dimethoate (Dimethoate 4EC): 1 pt/A; PHI 180d, REI 48h, Bee: H, Group 1B. Apply after last harvest. Systemic.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. Apply with companion aphicide.

malathion (Malathion 57EC): 1.5 to 2 pt/A; PHI 1d, REI 12h, Bee: H, Group 1B.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L.

pymetrozine (Fulfill): 2.75 oz/A; PHI 170d, REI 12h, Bee: L, Group 9B. Apply to ferns after harvest, and before populations build to damaging levels. Allow a minimum of 30 days between applications.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Asparagus Miner (*Ophiomyia simplex*)

This fly was introduced to North America from Europe and is present wherever asparagus is grown. It feeds only on asparagus, and is found primarily on older stalks bearing ferns. The adult fly is shiny black, 3-4 mm long, with clear wings. Larvae are whitish, legless, tapered at both ends, with black mouth hooks at one end. Pupation takes place in the larval mine on the stalk. Overwintering puparia are usually in mines near or below ground level. There are 2 generations per year. Adults emerge in May and lay eggs underneath the epidermis of stems, usually near the base of the plant. Larvae feed in June, pupate inside their larval mines, and a second generation of adults emerges and lays eggs in late-July or early-August. Second generation larvae feed through August and pupate in the fall, overwintering until the following spring. Larvae feed just beneath the surface of the stem, burrowing upwards or downwards and forming mines. While direct feeding damage can girdle stems if there are several mines per stalk, the effect of miners on yield is usually minimal and the injury is largely cosmetic. The most important injury from asparagus miner is due to its association with *Fusarium* spp. and its ability to vector this pathogen into the plant through feeding wounds. Cultural practices to reduce damage from asparagus miner include removing overwintering stalks and destroying wild asparagus in the vicinity of commercial plantings. Select varieties that are resistant to *Fusarium* to reduce disease (see Varieties, page 115).

acetamiprid (Assail 30SG): 25.3 oz/A; PHI 1d, REI 12h, Bee: M, Group 4A. Suppression only.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed after dark. Crooks (misshaped spears) are often caused by cutworms injuring tips at or just below the soil surface or feeding on the sides of young spears. For best results, make application between midnight and dawn while cutworms are feeding above ground. Synthetic pyrethroids (group 3A) may work best during cool weather in May. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

carbaryl (Sevin XLR PLUS): 1 qt/A prior to fern growth; 2 qt/A on ferns; PHI 1d, REI 12h, Bee: H, Group 1A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A.

permethrin (Pounce* 25WP): 3.2 to 6.4 oz/A; PHI 1h, REI 12h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 60d, REI 4h, Bee: M, Group 5. Scatter bait on soil around plants. For postharvest protection of ferns only.

■ Asparagus Beetles and Japanese Beetle

The common asparagus beetle (*Crioceris duodecimpunctata*) and spotted asparagus beetles (*Crioceris asparagi*) are less than 3/8" long, overwinter as adults in protected areas along

fields, feed and lay eggs in the crop, pupate in the soil, and have 2 or sometimes 3 generations per year. The common asparagus beetle (CAB) has a bluish-black body with cream-colored, square or rectangular spots, while the spotted asparagus beetle (SAB) is tan to orange with 12 round, black spots. Eggs of CAB are dark brown, laid standing on end in rows along the spears, with 3-10 in each cluster. During harvest, adult feeding by CAB on spears or the presence of CAB eggs can render the crop unmarketable. CAB larvae have 4 instars and are wrinkled, plump, hump-backed, and dull gray or brown with black head and legs. CAB larvae may cause severe defoliation of ferns and decline of the planting. SAB larvae are yellow or orange and feed only on berries. During harvest, scout for adults and eggs on sunny afternoons. Treat spears if >10% of the plants are infested with beetles or 1%-2% have eggs or damage. Scout ferns for all life stages of both pests and treat if 50%-75% are infested. If possible, spot spray along edges of planting where overwintering adults colonize the field and/or band insecticide over the row to help conserve natural enemies. Use selective insecticides on ferns. During harvest, snap or cut spears close to the soil surface daily and eliminate volunteer plants or treat them with an insecticide to use them as a trap crop. Disk old ferns lightly in the fall and clean areas around planting of debris to reduce overwintering populations. Eliminating female plants, and thus berries, can reduce or eliminate SAB populations. Japanese beetles may feed in ferns in mid-summer.

acetamiprid (Assail 30SG): 2.5 to 5.3 oz/A; PHI 1d, REI 12h, Bee: M, Group 4A.

carbaryl (Sevin XLR PLUS): 1 qt/A prior to fern growth; 2 qt/A on ferns; PHI 1d, REI 12h, Bee: H, Group 1A.

dimethoate (Dimethoate 4EC): 1 pt/A; PHI 180d, REI 48h, Bee: H, Group 1B. Asparagus beetle only. Apply after last harvest.

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OC}): 1 to 2 lb/A (foliar or soil drench); PHI 0d, REI 4h, Bee: M, Group M.

kaolin (Surround WP^{OC}): 12.5 to 25 lb/A or 25 to 50 lbs/100 gal water; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. Product residue may need to be washed off if applied to spears during harvest. Generally compatible as a tank mix with other insecticides.

malathion (Malathion 57EC): 1.5 to 2 pt/A; PHI 1d, REI 12h, Bee: H, Group 1B.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. Asparagus beetle only.

permethrin (Pounce* 25WP): 3.2 to 6.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. For Japanese beetle control, use high rate.

petroleum oil (Suffoil X^{OC}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. For beetle larvae only. Apply as needed.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A.; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 4 to 8 oz/A; PHI 60h, REI 4h, Bee: M, Group 5. Post-harvest protection of ferns from asparagus beetle only.

spinosad (Entrust SC^{OC}): 4 to 6 oz/A; PHI 60d, REI 4h, Bee: M, Group 5. Post-harvest protection of ferns from asparagus beetle only.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Grass Weed Control—new plantings and established beds

clethodim (Select Max): PHI 1d, REI 24h, Group 1. Apply 9 to 16 oz/A per application, minimum 14 days between applications. Do not exceed 64 oz/A per year. Will control grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Add 1 qt nonionic surfactant per 100 gal of spray (0.25% v:v). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluazifop (Fusilade DX): PHI 1d, REI 12h, Group 1. For grass weed control only. 16 to 24 oz/A per application, minimum 14 days between applications, and not to exceed 48 oz/A per year. Will control grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

sethoxydim (Poast): PHI 1d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14 days between applications. Do not exceed 5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

■ New Plantings

glyphosate (Roundup Power Max): REI 12h, Group 9. Preplant or stale seedbed application. Rate depends on target weeds, see label for rate selection. See Stale Seedbed Technique, page 107.

paraquat (Gramoxone SL 2.0*): restricted use. REI 12h, Group 22. Use 2.5-4 pts/A. Preplant or stale seedbed application. See Stale Seedbed Technique, page 107.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). See Stale Seedbed Technique, page 107.

pendimethalin (Prowl H₂O): PHI 14d, REI 24h, Group 3. Can be applied to newly planted crowns but NOT to newly seeded crop. When applying to newly planted crown

asparagus, assure crowns are fully covered with 2 to 4 inches of soil. Do not apply over the top of emerged spears or injury will occur. Use as a single application of up to 8.2 pt/A. On sandy soils do not use more than 2.4 pt/A. Apply uniformly to the soil surface at least 14 days prior to the first harvest. Cultivate or use Gramoxone Inteon to control emerged weeds.

linuron (Lorox DF): *PHI 1d, REI 24h, Group 7.* Can be used for pre- and postemergence control of many annual broadleaf weeds. See label for instructions on preemergence use after planting. For postemergence weed control, use 1 to 2 applications of 1-2 lbs/A when ferns are more than 6 inches tall. Spray emerged weeds when they are less than 4 inches tall. Use the lower rate on coarse-textured (sandy) soils low in organic matter, and the higher rate on fine-textured (silt and clay) soils. A second application can be made 1 to 3 months after the initial application, not to exceed a total of 4 lbs/A per year.

■ **Established Beds—Before spear emergence or after harvest season**

clomazone (Command 3ME): *PHI 14d, REI 12h, Group 13.* Make a single application of 2.6 pt/A in at least 10 gallons of water per acre prior to spear and weed emergence or after a clean harvest (must cover all asparagus plant parts with soil to prevent injury). Will control annual grasses and many broadleaf weeds.

diuron (Karmex DF): *REI 12h, Group 7.* Use 1-2 lbs/A on soils low in clay or organic matter, and 2-4 lbs/A on soils with high clay or organic matter. Use in the spring preemergence to both crop and weeds. If necessary, a second application can be made after cutting season. If planning two applications, do not exceed 3 lbs/A per application. The soil must be kept moist to activate diuron. If weeds start to germinate, cultivate lightly (not deeper than 1") and irrigate during cutting season. Do not use on newly seeded asparagus or on young plants or crowns during the first season. Do not use diuron on a bed the year it is to be abandoned and planted to another kind of vegetable.

flumioxazin (Chateau SW): *REI 12h, Group 14.* 3 to 6 oz/A per application, not to exceed 6 oz/A per season. For post-harvest applications, apply at least 2 weeks before fern emergence. For preemergence use, apply at least 14 days before spears emerge. Must be sprinkler or rainfall incorporated (0.5-0.75" of water) for preemergence weed control. Will control many broadleaf weeds and some grass species. If soil has been disturbed prior to application or if asparagus is not dormant, some crop injury may be observed. Can be applied to dormant asparagus tank-mixed with Gramoxone Inteon for burndown of emerged weeds. Use as an alternative to metribuzin, diuron, or terbacil. Do not use every year.

linuron (Lorox DF): *PHI 1d, REI 24h, Group 7.* Can be used as a single 2-4 lb/A application for preemergence weed control. Apply prior to spear emergence or after harvest for residual and postemergence control of many annual broadleaf weeds. Use the lower rate on coarse-textured (sandy) soils low in organic matter, and the higher rate on fine-textured (silt and clay) soils. See information about postemergence use in the following "Established Beds - Postemergence" section.

mesotrione (Callisto): *REI 12h, Group 27.* Apply 3 to 7.7 oz/A. Can be applied in the spring prior to spear emergence, or after harvest, or both, to control many winter and summer annual broadleaf weeds. Maximum of two application permitted, not exceed a total of 7.7 oz/A per year. When using Callisto after harvest, till the field or tank-mix with Gramoxone to eliminate emerged spears or crop injury may be observed as white or white streaks in the stems and fern when treated spears grow. Callisto provides excellent control of horseweed (also called marestail or stickweed), including glyphosate-tolerant strains, and common lambsquarter. Use the lower rate on coarse-textured (sandy) soils low in organic matter, and the higher rate on fine-textured (silt and clay) soils. Callisto does not control annual grasses. Tank-mix Callisto with a residual annual grass herbicide to control annual grasses. Add 1% crop oil concentrate (1 gal/100 gal of spray solution) or 0.25% nonionic surfactant (1 qt/100 gal of spray solution) if target weeds are emerged at the time of application.

metribuzin (Metribuzin 75): *PHI 14d, REI 12h, Group 5.* Can be applied as a single application in the spring prior to spear emergence (1.3 to 2.6 lb/A), or as two applications in the spring and after harvest. The total amount of metribuzin applied cannot exceed 2.6 lbs/A. If using two applications, apply 0.6-1.3 lbs/A in the spring and 1.3-2.0 lbs/A after harvest but before fern emergence. If field is to be disked, apply after disking but before crop emergence. Do not use on newly seeded asparagus or on young plants or crowns during first season. Do not apply to established beds after emergence. Fair on grasses.

napropamide (Devrinol 2-XT): *REI 12h, Group 15.* Use up to 2 gal/A. Incorporate thoroughly with irrigation prior to spear emergence if adequate rainfall does not occur within 24 hours of application. Apply only to stands that have been established for at least one growing season.

norflurazon (Solicam DF): *PHI 14d, REI 12h, Group 12.* Apply 2.5 to 5 lb/A, select rate based on soil type. See label for details. If adequate rainfall does not occur within 4 weeks of application, irrigation should be used to incorporate and activate. Apply after the cutting season. Controls most grasses and several broadleaf weeds. Also will suppress yellow nutsedge. Cannot be used unless planting is at least 12 months old, and should not be used if a crop rotation is planned within 24 months.

paraquat (Gramoxone SL 2.0*): restricted use. *PHI 6d, REI 12h, Group 22.* Use 2.5 to 4 pts/A, up to three applications per year. Apply prior to emergence of crop at least 2 years old, or after last clean cut harvest. Asparagus plants that have emerged at time of application will be killed.

pendimethalin (Prowl H₂O): *PHI 14d, REI 24h, Group 3.* Apply before spear emergence or after harvest. Do not apply over the top of emerged spears or injury will occur. Use as a single application of up to 8.2 pt/A. On sandy soils do not use more than 2.4 pt/A. Apply uniformly to the soil surface at least 14 days prior to the first harvest. Cultivate or use Gramoxone Inteon to control emerged weeds.

terbacil (Sinbar WDG): *PHI 5d, REI 12h, Group 5.* Apply prior to spear emergence, after a clean cutting, or after the last harvest. Do not apply more than 1.5 lb/A per

application, and if more than one application is made, total rate cannot exceed 2.5 lb/A per year. Use a lower rate on coarse-textured soils. Do not apply if roots are exposed or if the planting is weak; see label.

trifluralin (Treflan HFP): REI 12h, Group 3. Established plantings only. Can be used in the spring prior to spear emergence, after harvest before ferns emerge, or both. Rate based on soil texture and number of planned applications, see label for details.

■ Established Beds - Postemergence

glyphosate (Roundup Power Max): REI 12h, Group 9. Apply to emerged weeds well before spear emergence in the spring as contact with spears will result in serious crop injury. Can also be applied after cutting season, after removal of all growing spears and fern (clean cut). Contact with growing spears or fern will result in crop injury. For later application use directed or shielded sprays to prevent plant contact. Rate depends on target weeds, see label for rate selection.

halosulfuron (Sandea): PHI 1d, REI 12h, Group 2. For transplanted crowns and established beds only. For transplanted crowns, apply no sooner than 6 weeks after fern emergence. For established beds, apply before or during harvest season. May also be applied as a directed spray to the base of the ferns. Contact with ferns will cause yellowing. Will provide preemergence and postemergence control of many weeds. Use 0.5 to 1.5 oz/A per application. Do not apply more than 2 times per season and do not exceed 2 oz/A per year. See label for list of weeds and other precautions. Weed control may be reduced without the use of a surfactant.

linuron (Lorox DF): PHI 1d, REI 24h, Group 7. Use 1 to 3 applications of 1-2 lbs/A for postemergence weed control. Spray emerged weeds when they are less than 4 inches tall. Use the lower rate on coarse-textured (sandy) soils low in organic matter, and the higher rate on fine-textured (silt and clay) soils. DO NOT exceed 4 pounds of product per acre per year total (including any preemergence applications). See information about preemergence use in the previous “Established Beds—Before spear emergence or after harvest season” section.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. These include tank mixes with glyphosate (Roundup), sulfosate (Touchdown), and residual herbicides. See label for complete details.

s-metolachlor (Dual Magnum): REI 12h, Group 15. MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. This is a restricted label available only to growers who apply through the website www.farmassist.com and

agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

2,4-D sodium salt (Amine 4): PHI 3d, REI 48h, Group 4. Use 3-4 pt/A. Two applications are permitted, a minimum of one month apart. Spot spray when weeds appear. Keep spray off spears and ferns. 2,4-D is hazardous to most horticultural crops. Drift or sprays may seriously injure or reduce yields of these crops. May help to control unwanted seedling asparagus.

BASIL

Basil (*Ocimum* spp.) is a member of the mint family. There are several species and numerous interspecific hybrids. The most common culinary type is sweet basil, *O. basilicum*, which also has purple and lemon-scented cultivars. Specialty types include Thai (*O. tenuiflorum*), lemon (*O. americanum* X *O. citridorum*) and small-leaved bush types of various species and crosses. Basil seed is not always true to type. Try to obtain high-quality seed that is uniform with a high germination percentage.

Types and Varieties

Basil Varieties	
Sweet/Pesto Amazel - BDM Aroma 2 - F Elidia - F (intermediate) Everleaf - BDM, F (intermediate) Eleonora - BDM Genovese Italian Large Leaf Newton - F Nufar - F Prospera - BDM Rutgers Devotion - BDM Rutgers Obsession - BDM, F Rutgers Passion - BDM Rutgers Thunderstruck - BDM	Purple Red Rubin - BDM Dark Opal Amethyst Improved Purple Ruffles Bush Spicy Bush Spicy Globe Scented Sweet Dani (lemon) - BDM Lime Basil - BDM Holy Basil (medicinal) Cinnamon Basil Thai Sweet Thai
F: Some resistance to <i>Fusarium</i> wilt, BDM: Some resistance to basil downy mildew	

Basil downy mildew (*Peronospora belbahii*) was first reported in the United States 2007. Eleonora and Everleaf (aka Pesto Party) were the first downy mildew resistant sweet basil cultivars available in the US. Varieties with stronger resistance have since been released: Prospera, Amazel, and the Rutgers varieties Obsession, Devotion, Passion, and Thunderstruck. In trials conducted in NY in 2018, Amazel and Prospera showed the strongest disease resistance, followed by Thunderstruck, Passion, Devotion, and Obsession. None of these varieties are fully resistant to the disease but all will develop disease more slowly than fully susceptible varieties. Thai, lemon, and spice basil varieties are generally less susceptible than sweet basil varieties.

Soil Fertility

Basil grows well in a warm, well-drained soil in a wide pH range, although the typical vegetable crop range of pH 6.0-6.8 is ideal. Although adequate fertility is required (see Table

below), excess nitrogen applications can cause post-harvest discoloration and reduce flavor. Basil benefits from a sidedress application of nitrogen after the first or second cutting.

Planting

In New England, basil is most commonly transplanted, but because it is highly sensitive to cold (low 40s), it should not be set out until after danger of frost. Seeds will germinate within four to eight days at temperatures of 65°-80°F, with an optimum of 77°F. Transplants should be 4-6 weeks old. Topping when plants are 5"-6" tall encourages branching. Basil is often spaced at 6"-12" between plants in double rows. Tighter spacing will promote longer shoots for bunching.

If field soils are warm enough, basil can be direct-seeded in a well-prepared seedbed at a spacing of 8-10 seeds per foot and later thinned. Basil can be direct sown using an onion seeder. Pelleted seeds are also available to facilitate outdoor seeding.

Field Culture

Because of the lack of herbicides for weed control and the need for warm temperatures, basil is well suited to growing in raised beds covered with black plastic mulch. Drip irrigation allows consistent application of water while also reducing foliar diseases. Cultural management of insects, diseases and weeds is necessary because few pesticides are registered for use on basil. Summer weight row covers can help to exclude insect pests and create a more humid, tropical environment that is reminiscent of basil's native South Asian habitat. Some growers say that basil is more fragrant when grown in a wind-protected environment. However, high humidity is conducive to downy mildew, the most important pest of basil in recent years.

Harvest and Storage

Basil can be lightly harvested by pruning as early as 6 weeks after planting, with regular harvests starting a few weeks after that. Harvests should take place in the morning after the dew has left the plants. Depending on the intended use and market, individual leaves or entire stems may be harvested. Basil grown for culinary use should be harvested before flowering. Flavor will be adversely affected if allowed to flower. If grown for essential oil production, it should be harvested at full bloom. Plants will set seed if flower spikes are not removed as they appear. Sequential plantings can help ensure continuous production of quality shoots and leaves. However, harvesting basil by mid-summer can often prevent crop destruction from downy mildew.

Damage can be caused by rough handling, desiccation and chilling (<40°F). Cooling can be accomplished by rinsing in

55°F water, but foliage should be dried completely prior to packing. Maintenance of clean growing conditions, free from mud splash, enables some growers to avoid contact with water. Basil should then be stored at temperatures above 54°F.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

PESTICIDE USE IN GREENHOUSES AND HIGH TUNNELS:

Pesticides can be used on high tunnel and greenhouse crops if: 1) the crop and pest/disease is on the label, AND the products specifically says it can be used in the greenhouse; OR 2) the crop and pest/disease is on the label, AND the product is 'silent' about use in the greenhouse in the greenhouse. Products that specifically prohibit greenhouse use cannot be used in greenhouses or high tunnels regardless of the crops or pests/diseases listed on the label.

Purchase disease-free seed. Use resistant varieties where feasible. Promptly remove any stock plants that are diseased or low in vigor. Use separate greenhouses for herb production and keep stock plants separate from production areas. There are few fungicides or bactericides registered for herbs.

■ Bacterial Leaf Spot (*Pseudomonas cichorii*)

Disinfect all benches, equipment, and pots. Purchase culture-indexed plants and disease-free seed. Avoid overhead irrigation. Discard infected plants. Clean production areas thoroughly after harvest as bacteria can survive in dead leaves.

■ Botrytis blight and stem canker (*Botrytis cinerea*)

Management of environmental conditions such as temperature, relative humidity and duration of leaf wetness is vital to *Botrytis* control. Control weeds and remove plant debris between crops and during production. Provide good air circulation and reduce humidity within the plant canopy by proper plant spacing, plant height, and fertility. Water in the morning, never late in the day.

Bacillus amyloliquefaciens F727 (Stargus⁰⁶): 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. Apply preventatively in a minimum of 50 gallons of water/A.

Plant Nutrient Recommendation According to Soil Test Results for Basil

BASIL	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	100	120	60	30	0	100	50	25-50	0
Sidedress after 1st or 2nd cutting	15-30	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	115-130	120	60	30	0	100	50	25-50	0

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12.* Do not make more than 2 consecutive applications.

potassium bicarbonate (MilStop^{OG}): 2.5 to 5.0 lb/100 gal; *PHI 0d, REI 4h, Group NC.* See label for small volume application rates.

***Ulocladium oudemansii* (BotryStop^{OG}):** 2.0 to 4.0 lbs/A; *REI 4h, Group NC.* Begin application when conditions are conducive to disease development.

■ **Damping-off, Crown and Root Rot (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp. & *Phytophthora* spp.)**

Use pasteurized soil or soil-less mixes for transplant production. Disinfect all flats, pots, and tools. Use bottom heat to promote rapid seed germination. Avoid over-watering, over-fertilizing, and overcrowding. Promptly rogue out infected plants. Manage fungus gnats and shoreflies.

***Bacillus amyloliquefaciens* F727 (Stargus^{OG}):** 2.0 to 4.0 qt/A; *PHI 0d, REI 4h, Group 44.* Apply preventatively in a minimum of 50 gallons of water/A.

mefenoxam (Ridomil Gold SL): 0.5 to 1.0 pt/A; *PHI 21d, REI 48h, Group 4.* *Pythium* and *Phytophthora* ONLY.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; *REI 12h, Group 12.* For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

potassium phosphite (K-Phite): 1.0 to 4.0 qt/A; *PHI 0d, REI 4h, Group.* Apply in a minimum of 20 gal water/A.

■ **Downy Mildew (*Peronospora belbahii*)**

Downy Mildew of basil can be serious in both field and greenhouse production. Start with certified, disease-free seed. Scout crops regularly and promptly remove and destroy infected plants. Reduce leaf wetness duration by plant spacing, improving air circulation, and watering when plants will dry quickly. In the greenhouse, use a combination of heating and venting to reduce humidity and condensation, especially when warm days are followed by cool nights. Varieties with some resistance to downy mildew are available (see varieties, page 120).

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11.* Registered for field use.

***Bacillus amyloliquefaciens* F727 (Stargus^{OG}):** 2 to 4 qt/A; *PHI 0d, REI 4h, Group 44.* Apply preventatively in a minimum of 50 gallons of water/A.

cyazofamid (Ranman): 2.75 to 3.0 fl oz/A; *PHI 0d, REI 12h, Group 21.* Registered for greenhouse use.

fenamidone (Reason SC): 6.0 fl. oz/A; *PHI 2d, REI 12h Group 11.* Greenhouse and field. Do not alternate with other Group 11 fungicides.

hydrogen peroxide and peroxyacetic acid (Oxidate 2.0^{OG}): 1:2 to 1:4 dilution; *PHI 0d, REI 0h.* Do not tank mix with copper.

mandipropamid (Micora): 8 fl oz/A; *PHI 1d, REI 4h, Group 40.* NOTE: greenhouses use limited to structures with permanent flooring ONLY. Not labeled for field use.

mandipropamid (Revus): 8 fl oz/A; *PHI 1d, REI 4h, Group 40.* Labeled for field use.

oxathiapiprolin (Orondis Ultra A): 2.0 to 4.8 fl.oz/A; *PHI 0d, REI 4h, Group 49.* Begin foliar application prior to disease development.

potassium bicarbonate (MilStop^{OG}): 2.5 lb/100 gal; *PHI 0d, REI 1h, Group NC.* Thorough coverage is essential. Registered for greenhouse and field use. See label for small volume application rates.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33.* Do not apply to plants that are heat or moisture stressed.

***Streptomyces lydicus* (Actinovate^{OG}):** 6 to 12 oz/A; *PHI 0d, REI 1h, Group NC.*

■ **Fusarium Wilt (*Fusarium oxysporum* f.sp. *basilici*)**

Fusarium wilt is very difficult to manage as it can persist in the soil or hydroponic system for many years. Practice strict sanitation. Begin with disease-free seed or treat seed with hot water or dilute bleach. The basil varieties Aroma 2, Nufar, Newton and Rutgers obsession have some resistance to Fusarium wilt. *Fusarium* is a soil inhabitant that can become established in the field. Promptly remove and destroy all infected plants, infested soil, and plant debris. Rotate crops, excluding members of the mint family, which can be symptomless carriers of *Fusarium*.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Aphids**

For more information on biology, see aphids in the pepper section.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; *PHI 0d, REI 4h, Bee: L, Group un.* When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

***Beauveria bassiana* (Mycotrol ESO):** 8 to 32 oz/A; *PHI 0d, REI 4h, Bee: L, Group 22.* Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after application to see control.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.2 oz/A foliar; *PHI 14d soil, 7d foliar, REI 12h, Bee: H, Group 4A.*

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. Repeat application every 2 to 3 days until pest is under control. For enhanced and residual control apply with companion labeled aphicide.

***Isaria fumosorosea* Apopka Strain 97 (PFR-97 20% WDG^{OC}):** 1 to 2 lb/A (foliar or soil drench); PHI 0d, REI 4h, Bee: M, Group M.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Japanese and Oriental Beetles

Beetles move into basil after emerging from soil in turf, pastures or fallow areas, starting in late June and peaking in July. Adult beetles skeletonize leaves as they feed. Row covers can prevent feeding, but watch for build-up of aphids due to exclusion of natural enemies. The basil variety Nufar is very attractive to Japanese beetles and can be used for a trap crop.

azadirachtin (Azatin O^{OC}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

***Isaria fumosorosea* Apopka Strain 97 (PFR-97 20% WDG^{OC}):** 1 to 2 lb/A (soil applications only); PHI 0d, REI 4h, Bee: M, Group M.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

Suggestions for weed management in basil include use of the Stale Seedbed Technique and use of plasticulture. Both glyphosate (Roundup) and pelargonic acid (Scythe) are registered for stale seedbed use. Flaming can also be used. Stale seed beds can be used between plastic mulch (be careful with flaming as it melts the plastic). Basil usually grows quickly and shades the planting hole in plasticulture, out-competing weed growth. Apply the plastic at least 2 to 3 weeks prior to planting and kill the weeds between the mulch prior to setting the basil plants on the plastic. On bare ground culture, keep cultivations shallow to protect crop roots. Do not move soil into the crop row as basil plants may be more susceptible to diseases when soil is mounded against the stems of the crop.

■ Herbicides Used Preemergence to Weeds

napropamide (Devrinol 2-XT): REI 12h, Group 15. Apply 2 to 4 qt/A as a preplant/preemergence application to weed-free soil surface. Apply with ground spray equipment only, in 20-100 gallons of water per acre. Apply to a weed free surface. Shallow incorporate no deeper than seeding depth or sprinkler irrigate within 24-72 hours using sufficient water to wet the soil to a depth of 2 to 4 inches. Use the lower rate on light soil (coarse textured - sandy) and the higher rate on heavy soil (fine textured - clay).

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 14d, REI 24h, Group 1. Has not been tested on all varieties. Crop tolerance should be verified on a small area of the crop at the desired rate. If no crop response is evident seven days after treatment, Select Max Herbicide may be used on the entire field at the rate tested. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14 days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

BEAN: SNAP, LIMA AND DRY

Snap and dry beans (*Phaseolus vulgaris* and *P. coccineus*) are relatively easy to grow in New England while lima beans (*P. lunatus*) are more difficult. Other specialty bean crops include Edamame soybeans (*Glycine max*) and fava or broad beans (*Vicia faba*). Beans should be planted in well-drained soil, and should not be repeatedly planted in the same field (use at least a 3-year rotation) to avoid soil-borne diseases.

Plant only when soil temperatures have reached 60°F (late May-early June). Optimum seed germination occurs at soil temperatures above 70°F. Irrigation may be necessary at time of bloom in order to ensure maximum pod set under dry soil conditions. Temperatures above 90°F or below 50°F cause poor pod set.

Types and Varieties

Snap beans can have green, purple or yellow (wax) pods, and grow in bush (*P. vulgaris*) or vine/pole forms (*P. coccineus*). Pods are oval, round, or flat (Italian types), depending on cultivar. Filet beans are ones that have slender stringless pods that stay small and thin. Good commercial yields for fresh market are 200 bushels or more per acre.

Lima beans (*P. lunatus*) are of minor importance in most areas in New England. Seed germination requires warm soil. A relatively long time to maturity reduces the length of the harvest season and restricts production in northern New England. A good yield of shelled lima beans is 3,000 lb/A.

Dry beans. In recent years, a significant acreage of pea beans and a small, but important, acreage of light red kidney varieties have been grown in northern New England. Vermont and Maine have a thriving tradition of growing heirloom varieties. For additional information about dry beans, see the Northeast Dry Bean Production Guide (University of Vermont Extension, March 2017) at <https://cdn.sare.org/wp-content/uploads/20171204115634/NEDryBeanProductionGuide2017.pdf>.

Snap, Lima and Dry Bean Varieties	
Snap Beans - green Bronco - BCMV Concesa - BCMV, HB Contender - BCMV, PM Dusky - BCMV, PM, HB, BBR Jade II - BCMV, BR Pony Express - BCMV, CT Provider - BCMV, PM Tema - BCMV Boone - BCMV, PM, HB, BBR Fortex - pole	Lima Beans Fordhook 242 Eastland - DM King of the Garden - pole Dry Beans Jacob's Cattle Maine Yellow Eye Pinto Redkote Kidney - HB Seafarer Pea Bean - A, HB, BCMV White Marrow Marfax
Snap Beans - Italian flat-podded Greencrop - BCMV Romano 942 - BCMV Roma II - BCMV Navarro - BCMV Romano Gold (yellow)	Snap beans - yellow/wax Carson - BCMV, A Rocdor - BCMV, A Eureka - BCMV, BBR Monte Gusto - pole
Snap Bean - slender filet Concador Maxibel Nickel Soleil (yellow) Tavera - A, BCMV Velour (purple)	Snap beans - purple Amethyst Royal Burgundy Carminat - pole
Resistant to: A: Anthracnose; BBR: Bacterial Brown Rot; BR: Bean Rust; BCMV: Bean Common Mosaic Virus; CT: Curly Top Virus; DM: Downy Mildew; HB: Halo Blight; PM: Powdery Mildew Other codes: pole = pole beans (all others are bush)	

Soil Fertility

Apply lime according to soil test to maintain soil pH at 6.5-6.8.

Apply no more than 80-100 lb/A combined weight of nitrogen and potash through the planter. Because beans are sensitive to salt or ammonia injury, keep fertilizer 2-3 inches away from the seed.

A sidedressing of 30 lb nitrogen/A at prebloom may extend harvest period of snap beans and increase yields, especially on sandy soils. Machine harvested snap or dry beans are unlikely to need sidedressing.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Beans can suffer from zinc (Zn) deficiency or boron (B) toxicity. If soil tests report less than 1.0ppm Zn, then add 10

lbs per acre zinc sulfate to the starter fertilizer. If soils contain more than 0.5ppm B, then avoid growing beans in this field.

Planting

Seeds may be inoculated with the appropriate isolates of Rhizobium to increase nitrogen fixation and yields. When purchasing inoculum, purchase fresh inoculum each year, and follow suppliers' guidelines to make sure that you are purchasing the correct strains to inoculate each crop species.

Bush Snap Beans: Plants should be spaced 1.5"-2" within rows and 18"-36" between rows. Use the higher plant population under a more favorable environment. Sow 75-100 lb of seed/A (approximately 0.5 lb/100' of row) depending on seed type and percent germination. Plant seed 1"-1.5" deep, depending on soil type and/or soil moisture content. Repeat seeding every 2-3 weeks for a continuous supply.

Pole Beans: Pole beans can be supported by a bean trellis of a large mesh nylon material or chicken wire fencing. Removing the plants from the fence is a chore, while nylon mesh is disposable. The traditional manner is to use a 4 pole tepee method. When using the trellis or fence method, plant seeds 1"-2" deep, 6" apart, in rows 4' apart. For the tepee method, plant 6-7 seeds around each pole. One lb of seed will plant 240' of row or around 150 poles.

Lima Beans: Plants should be spaced 4"-6" within rows and 18"-36" between rows. Use 40-60 lb seed/A (4-6 oz/100' of row). Plant 1" deep in moist heavy soils and 2" in dry, sandy soils.

Dry Beans: Plants should be spaced 2"-3" within rows and 28"-36" between rows. Rate of seeding depends on seed size, percent germination, time of planting, and row spacing (check seed supplier recommendations for each cultivar). Plant 1" deep in moist heavy soils and 2" in dry, sandy soils.

Harvest

Snap beans: Snap beans for fresh market should be harvested when they reach the desired size. Beans should be harvested when the pod is bright green and fleshy, and the seeds are small and green. Pods should snap easily when bent. Large-scale growers should investigate mechanical harvesters. Hand-harvest multiple times or machine-harvest once when the highest percentage of marketable beans are mature. Optimum storage conditions are 41-45°F at 95-100% relative humidity, but storage time is limited. Temperatures of 38°F and lower may cause chilling injury. After >10% weight loss, beans will not be marketable. Avoid storing or shipping beans with ethylene-generating fruits and vegetables.

Plant Nutrient Recommendation According to Soil Test Results for Bean: Snap, Dry, and Lima

BEAN: SNAP, DRY, LIMA	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P2O5 per acre				Potassium (K) Lbs K2O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast or Planter*	50	100	75	0-50	0	100	75	0-50	0
TOTAL RECOMMENDED	50	100	75	0-50	0	100	75	0-50	0

*DO NOT exceed a total of 80lb N/A plus K₂O as a preplant incorporate, if necessary.

Lima beans: Harvest should take place when 2/3-3/4 of the pods have filled and are yellowing, but before any pods have dried. Other harvest practices are similar to that for dry beans.

Dry beans: Most require 90-100 days to mature. Dry beans should not be harvested until the majority of pods have turned yellow and thoroughly matured, but before the pods dry to the point of shatter. The mature beans should be so hard that you cannot easily bite into the seed. Harvesting in the morning while there is still dew can minimize loss to shatter. Mechanized harvesting can be done with a puller-cutter, which will uproot or cut the entire plant and lay it on the ground in windrows as the machine moves along the field. Windrows can be combined when beans have dried to 18% moisture. Once shelled, beans should be conditioned using a low temperature and dried to a moisture level of 15-16%, then stored in rodent and insect proof bins at temperature ranging from 35° to 55°F.

■ Defoliants/Harvest Aids for Dry Beans

flumioxazin (Valor SX): 5 day PHI. Apply when crop is mature and at least 80% of the pods are yellowing and mostly ripe with no more than 40% (bush type beans) or 30% (vine type beans) of the leaves still green in color. To ensure thorough coverage use 15-30 gallons spray solution per acre. Do not apply more than 3 oz/A during a single application and do not apply more than 3 oz/A during a single growing season. Adjuvant required. Crop oil concentrate or methylated seed oil at 2% v/v should be used. A spray grade nitrogen source (either ammonium sulfate at 2-2.5 lb/A or a 28-32% nitrogen solution at 1-2 qt/A) may also be added to the spray mixture to enhance desiccation. Can be tank mixed with glyphosate or paraquat to increase control of emerged weeds and aid in harvest.

paraquat (Gramoxone SL 2.0): Apply 0.75-1.3 pt/A; PHI 7 d, REI 48h, Group 22 in 20 gal water with ground equipment or in a minimum of 5 gal water with aerial equipment. Add spreader (nonionic) at 1 qt per 100 gal spray mix. For vining-type beans or bush-type with lush growth, use a single application of the higher rate. May also be applied as a split application. Do not make more than two applications or exceed a total of 1.5 pts/A. The split application method may improve vine coverage. Apply when the crop is mature and at least 80% of the pods are yellowing and mostly ripe with no more than 40% (bush type) or 30% (vine type) of the leaves still green in color. Do not apply when weather conditions favor spray drift. A drift control agent may be included to reduce spray drift. Do not use on Fava beans.

saffluenacil (Sharpen): 2 day PHI. Make a single application of 1-2 fl oz/A in a minimum spray volume of 10 gallons/A over the top of dry edible beans that have reached physiological maturity (at least 80% yellow/brown pods, and no more than 30% of leaves still green for vine-type beans/lentils or no more than 40% of leaves still green for bush-type beans). Thorough spray coverage and a methylated seed oil plus ammonium-based adjuvant system (refer to the Additives Section of label for details) are required for optimum desiccation activity. Allow up to 10 days for optimum desiccation effect.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Anthracnose (*Colletotrichum lindemuthianum*)

Anthracnose is common in beans and is primarily a seed-borne disease surviving on dry, undecomposed residues for up to 5 years. Symptoms begin as red spots on leaves and pods that develop into black lesions. Leaf veins can turn red-brown. Start with certified, disease-free seed and use resistant cultivars. Fungicides may be applied as seed treatments or foliar sprays.

azoxystrobin (Quadris): 6.2 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 2.4 pt/A; PHI 14d, REI 12h, Groups 11 & M5. DRY bean only. See label for tank mix precautions.

azoxystrobin plus propiconazole (Quilt): 14 fl oz/A; PHI 7d succulent; PHI 14d dry, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 1.375 to 3.0 pt/A; PHI 7d (snap) to 14d (dry), REI 12h, Group M5.

fluxapyroxad plus pyraclostrobin (Priaxor): 4.0 to 8.0 fl oz/A; PHI 7d, REI 12 h, Groups 7 & 11.

penthiopyrad (Fontelis): 14.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

potassium bicarbonate (MilStop^{OG}): 2.5 lb/100 gal; PHI 1d, REI 4h.

propiconazole (Tilt): 4.0 fl oz/A; PHI 7d, REI 12h, Group 3.

pyraclostrobin (Headline): 6.0 to 9.0 fl oz/A; PHI 7d (succulent) to 21d (dry), REI 12h, Group 11. Apply at the beginning of flowering. Do not make more than 2 applications/season or alternate with other Group 11 fungicides.

thiophanate-methyl (Topsin 4.5 FL): 30 to 40 fl oz/A; PHI 14d (snap) to 28d (dry), REI 24h (succulent); 72h (dry), Group 1.

■ Downy Mildew-Lima Beans (*Phytophthora phaseoli*)

Downy mildew resistant lima bean varieties are available. Rotate to non-susceptible crops. Apply seed treatments to protect germinating seedlings against soil-borne inoculum. Plow under infected debris in fall. Rotate with crops other than beans for two years.

chlorothalonil (Bravo Weather Stik): 1.375 to 3.0 pt/A; PHI 7d (snap) to 14d (dry), REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.5-1.25 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Alette.

cyazofamid (Ranman): Succulent beans ONLY. 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Tank mix with organosilicone or non-ionic surfactant.

mefenoxam (Apron XL): 1.28 fl oz/100 lb seed; REI 48h, Group 4. Seed treatment.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; PHI 0d, REI 4h, Group 33. Do not apply to heat or moisture stressed crops or plants recently treated with copper.

potassium bicarbonate (MilStop^{OG}): 2.5 lb/100 gal; PHI 1d, REI 4h.

pyraclostrobin (Headline): 6.0 to 9.0 fl oz/A; PHI 7d (succulent) to 21d (dry), REI 12h, Group 11. Do not make more than 2 applications before alternating to a non-Group 11 fungicide.

■ *Rhizoctonia solani*

Rhizoctonia stem canker caused by strains of the soil-borne fungus *Rhizoctonia solani* is common throughout the world on peas and beans. The pathogen survives between crop seasons as sclerotia (survival structures), mycelium in the soil, or on or in infected plant debris. It is spread in infested soil or plant debris by wind, rain, irrigation water, and machinery. When a soil becomes infested, it remains so indefinitely. Seedlings and young plants are highly susceptible to infection and disease severity is increased by low soil temperatures and compaction. Seed decay and damping off can be controlled by using high-quality seed, with high germination and vigor, and by practices that encourage rapid germination and emergence. Seed treatments are not effective against infections later in the season. The disease may be reduced by sowing seed as shallowly as possible in warm, moist soil. Land preparation that minimizes soil compaction and structural damage will lessen disease severity. Rotate crops with a cereal or pasture crop (avoid beets, beans, brassicas and potatoes which increase inoculum). Cover crops and other practices that increase organic matter and improve soil structure are recommended. Some brassica crops (mustard, rape) used as green manure have been reported to be disease suppressive. Avoid incorporating green manure immediately before planting or damaging roots by shallow cultivation. Fungicides can manage *Rhizoctonia* root rot on young seedlings if applied as a seed treatment or soil drench.

***Bacillus amyloliquefaciens* F727 (Stargus^{OG}):** 2 to 4 qt/A; PHI 0d, REI 4h, Group 44. Apply preventatively in a minimum of 50 gallons of water/A.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi.

PCNB (Blocker 4F): 2.3 to 3.3 fl oz/1,000 ft.; REI 12h, Group 14.

***Trichoderma asperellum*, *T. gamsii* (Biotam^{OG}):** See label for in-furrow, drench, and broadcast rates; PHI 0d, REI 4h, Group NC.

thiram (Thiram 42-S): 2.0 fl oz./100 lb seed; REI 12h, Group M3.

■ Rust (*Uromyces appendiculatus*)

Symptoms are most visible on the undersides of leaves. Symptoms begin as tiny white raised spots called pustules

that break open to produce distinct red spots with dust-like spores (uridinospores) which easily brush off. Spots may be surrounded by yellow halos in some varieties. Severely infested leaves fall off plants. Overwintering spores (teliospores) are black in color. Plant resistant varieties. Plow under crop debris immediately after harvest. Bury or otherwise destroy crop residues to reduce overwintering inoculum. Rotate away from beans for 2 years or up to 5 years in reduced tillage. Avoid overfertilization with high levels of nitrogen, but ensure adequate potassium. Disinfect poles in production of pole beans. Avoid long periods of leaf wetness when irrigating during times when temperatures are warm.

azoxystrobin (Quadris): 6.0 fl oz/A; PHI 0d, REI 4h, Group 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 2.4 pt/A; PHI 14d, REI 12h, Groups 11 & M5. DRY bean only. See label for tank mix precautions. Not labeled for soybean.

azoxystrobin plus propiconazole (Quilt): 14 fl oz/A; PHI 7d succulent; PHI 14d dry, REI 12h, Groups 11 & 3.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

chlorothalonil (Bravo Weather Stik): 1.375 to 3.0 pt/A; PHI 7d (snap) to 14d (dry), REI 12h, Group M5.

myclobutanil (Rally): 4.0 to 5.0 oz/A; PHI 0d, REI 24h, Group 3. Observe a 30-day plant back interval. Snap beans only.

penthiopyrad (Fontelis): 14.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propiconazole (Tilt): 4.0 fl oz/A; PHI 7d, REI 12h, Group 3.

pyraclostrobin (Headline): 6.0 to 9.0 fl oz/A; PHI 7d (snap) to 21d (dry), REI 12h, Group 11. Do not make more than 2 applications per season or rotate with another Group 11 fungicide.

sulfur (Microthiol Dispers^{OG}): 3.0 to 10.0 lb/A; PHI 0d, REI 24h, Group M2.

■ Seed Decay

Buy treated seed. Do not use treated seed for food or feed.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.12 to 1.0 lb/A as a soil drench; PHI 0d, REI 4 h, Group 44.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi.

mefenoxam (Apron XL): 0.16 to 0.64 fl oz/100 lb seed; REI 48h, Group 4. For Pythium damping off. Early season Phytophthora protection (0.64 fl oz/lb seed).

thiram (Thiram 42-S): 3.0 lb (lima) 2.0 lb (snap & dry)/100 lb seed; REI 12h, Group M3.

■ White Mold (*Sclerotinia sclerotiorum*)

Space plants to allow good air circulation. Plant on well-drained soil. *Sclerotinia* produces sclerotia, which are hard, black structures from 1/16" to 1/2" in length, inside or on the surface of infected tissue. Sclerotia can survive for years in the soil and are responsible for initiating disease. Germination of sclerotia and initiation of disease are dependent on prevailing weather conditions. Optimum temperature for sclerotia to germinate is about 52°F but some sclerotia germinate over a wider range of temperatures. Germination is also dependent on continuous soil wetness for 10 days.

Many vegetable crops and weeds are susceptible to this fungus; corn and grasses are not. Lettuce, cabbage, tomato, carrot, brassicas and snap beans are among the most susceptible and should not be grown on land known to be contaminated with *Sclerotinia*. After an episode of disease, rotate away from susceptible crops for 7 years. A single infected head of cabbage may produce more than 1,000 sclerotia. Removal of diseased plant material as soon as possible is highly recommended.

Bacillus amyloliquefaciens F727 (Stargus^{OG}): 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. Apply preventatively in a minimum of 50 gallons of water/A.

boscalid (Endura): 8.0 to 11.0 oz/A; PHI 7d (succulent) to 21d (dry), REI 12h, Group 7. Do not make more than 2 applications per season.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

Coniothyrium minitans (Contans WG): Apply 1.0 to 4.0 lb/A in 20 to 50 gal water; REI 4h, Group is not applicable. Spray on the soil surface and incorporate into the top 2" of soil. Fall application is best or 3 to 4 months before planting to allow for the biocontrol agent to infect the sclerotia of *Sclerotinia*. OMRI listed.

fluzinam (Omega 500F): 0.5 to 0.85 pt/A; PHI 14d edible pod, PHI 30d dry and lima beans, REI 72h, Group 29.

iprodisone (Rovral 4F): 1.5 to 2.0 pt/A; PHI 14d, REI 24h, Group 2. See label for restrictions.

PCNB (Blocker 4F): 2.2 to 3.3 fl oz/1,000 ft.; REI 12h, Group 14.

penthiopyrad (Fontelis): 16.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

thiophanate-methyl (Topsin 4.5 FL): 20 to 30 oz/A; PHI 14d snap or lima and 28d dry, REI 24h (succulent) and 72h (dry), Group 1.

Trichoderma asperellum, T. gamsii (Bioten^{OG}): See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

■ Bacterial Diseases (*Pseudomonas* spp. and *Xanthomonas* spp.)

Bacterial leaf diseases include: bacterial bean blight (*Xanthomonas campestris* pv. *phaseoli*), bacterial brown spot (*Pseudomonas syringae* pv. *syringae*), and halo blight (*Pseudomonas syringae* pv. *phaseolicola*). Plant western-grown,

disease-free seed. Eliminate wild cherries and lilacs near bean fields. Do not cultivate or harvest when plants are wet. Use a 2-year rotation. Plow under infected debris in fall.

copper hydroxide (Kocide 3000): 0.5 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Do not apply with a spray solution having a pH less than 6.5 or tank mix with Aliette.

■ Bean Common Mosaic Virus (BCMV)

In addition to mosaic and lesions of the foliage, BCMV can also cause blackened roots. Several different strains of the virus are recognized; the symptoms and host ranges vary according to the strain. The virus can be seed-borne and is transmitted by at least 12 species of aphids in a nonpersistent manner. Resistant varieties are available and constitute the most reliable means of control. Seed treatment, insecticides, and roguing of diseased plants are of little value.

■ Bean Yellow Mosaic Virus (BYMV)

Many strains of this virus are known. Symptoms of BYMV are easily confused with BCMV. However, BYMV is not seed-borne and unlike BCMV, BYMV is spread in a persistent manner by more than 20 species of aphids. Entire plantings may become infected, resulting in substantial losses in yield. Disease outbreaks are often correlated with the presence of virus-source plants such as sweet clover, white clover, crimson clover, and *Gladiolus* sp. Since the virus overwinters in legumes such as clover and vetch, beans should be planted at least 800' away. Insecticides applied early will reduce spread. Plant mosaic resistant varieties (see varieties list, page 124).

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids

Several species of aphids may probe, feed and cause direct damage or transmit disease in dry or snap beans: soybean, bean, pea, yellow clover, and green peach aphid. Soybean aphid (*Aphis glycines*) reproduces in soybeans but not green or dry beans; however, this species can colonize, inflict feeding injury and transmit virus to green and dry beans. Soybean aphid is found on beans in New York and in the Midwest, with higher pressure in hot dry summers. It has been less important in New England but could increase, especially in soybean production areas. Virus diseases can be spread by aphids; however, using insecticides to control aphids is not effective for reducing these viruses. Generally, aphids in beans are controlled by natural enemies. Scout for aphids on

undersides of leaves or terminal shoots. Treat only if aphids are well distributed throughout the field (50% or more of terminals with 5 or more aphids), natural enemies are lacking, and population is increasing. Use selective products for other pests to conserve natural enemies of aphids and to protect bees. Systemic insecticide may be used as seed treatment or at planting. Avoid planting beans near alfalfa or soybean. See Peppers for more information about green peach aphid.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A. Edible-podded and succulent shelled peas and beans only.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d dried, 1d fresh lima, REI 24h, Bee: H, Group 1B. Use on succulent green beans (snap) not permitted, except those grown for seed. Not labeled for control of Black Bean aphid.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.9 oz/A; PHI 1d succulent shelled or edible-podded, 21 d dried, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Succulent beans only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

dimethoate (Dimethoate 4EC): 8 to 16 oz/A; PHI 0d, REI 48h, Bee: H, Group 1B.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 3A. For Pea aphid.

flonicamid (Beleaf): 2.8 oz/A; PHI 7d, REI 12 h, Bee: L, Group 29.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d fresh; 21d dry, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A foliar, 7 to 10.5 oz/A soil; PHI 7d foliar, 21d soil, REI 12h, Bee: H, Group 4A.

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OG}): 1 to 2 lb/A foliar; PHI 0d, REI 4h, Bee: M, Group M.

lambda-cyhalothrin (Warrior*II): 1.28 to 1.92 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1 d fresh at up to 1.5 pt/A, 3d for over 1.5 pt/A; 14 d dry, REI 48h, Bee: H, Group 1A.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

sulfoxaflor (Transform WG): 0.75 to 1 oz/A; PHI 7d, REI 24h, Bee: H, Group 4C. Do not apply until after petal fall.

thiamethoxam (Cruiser 5FS): 1.28 oz/100 lb of seed; REI 12h, Bee: H, Group 4. Systemic seed treatment. For early-season protection from aphids. Use standard slurry seed treatment equipment which provides uniform coverage of seed.

■ Cutworms

Cutworm larvae may be dull gray, brown, or black and may be striped or spotted, depending on the species. Another distinguishing quality is their act of rolling into a tight C-shape if disturbed. The two major species are the variegated cutworm (*Peridroma saucia*), which feeds on lower leaves and petioles, and the black cutworm (*Agrotis ipsilon*), which largely feeds at the soil surface and below on roots and lower stems. The black cutworm will occasionally feed on leaves. Both are nocturnal feeders and take refuge under soil clumps, stones, vegetation, and other places during the day. Cutworms find weedy or minimum-tillage fields especially attractive sites to lay their eggs. Seedlings are most affected; look for cut stems or foliage feeding. Scout across the field, as injury may be limited to a few small areas. Control is warranted if overall plant stand or survival is threatened. Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed on stems after dark. For best results, make application between midnight and dawn while cutworms are feeding aboveground. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d dry 1 d fresh lima, REI 24h, Bee: H, Group 1B. Use on succulent green beans (snap) not permitted, except those grown for seed.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, 21d dried, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Succulent beans only.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 14d, REI 12h, Bee: L, Groups 16 & 28.

carbaryl (Sevin XLR Plus): 1 to 1.5 qt/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 1A. Most effective on species which feed on upper portions of the plant.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 5 to 8 oz/A; PHI 7d edible-podded and succulent shelled, 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 3A. On snap beans, use only as a seedling spray. No restriction on dry beans.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.60 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 3d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

■ European Corn Borer (*Ostrinia nubilalis*), Corn Earworm (*Helicoverpa zea*), and Cabbage Looper (*Trichoplusiani*)

These caterpillars are occasional pests of bean in New England. See Sweet Corn for more details on European corn

borer (ECB) and corn earworm (CEW), and Cabbage and Other Brassica Crops for more information on cabbage looper (CL). In beans, ECB eggs are laid under leaves and larvae feed in stems, then bore into pods. The bloom period is most attractive for egg-laying. If a preferred host such as corn is not available, eggs will be laid in beans. This may occur where early beans are planted after a corn crop the previous year, or where late beans are near a maturing corn crop when the second ECB generation emerges. The most susceptible period in snap bean is from bud stage (about 26 days before harvest) to pod formation (12 days before harvest), and in dry bean is for the 4 weeks preceding the onset of pods drying. Infestation depends on synchrony of ECB flight and bean stage. The most effective timing for a single insecticide application is bloom or pod formation. CEW or CL may lay eggs in beans when migratory flights are very high. CEW or CL caterpillars feed on leaves, buds, flowers, and pods, often damaging the beans. CEW and CL feeding holes may be larger than ECB entry holes. The impact of these caterpillars on overall plant growth and yield is minimal, but the tolerance for caterpillar infestation is extremely low in processing beans where larval contamination must be avoided. The most practical and effective control for ECB is to avoid planting early beans where corn was grown the previous year or late beans near corn where ECB may emerge. Monitor moth activity in corn using pheromone traps or refer to pest alert networks to detect peak or high flights. Scout if flights are high during the susceptible period of bean growth, looking for wilted or chewed trifoliolate leaves, larvae, or pod injury. There is no set threshold for treatment.

acephate (Orthene 97): 0.5 to 1 lb/A for CL; 3/4 to 1 lb/A for ECB and CEW; *PHI 14d dry, 1d fresh lima, REI 24h, Bee: H, Group 1B.* Use on succulent green beans (snap) not permitted, except those grown for seed.

alpha-cypermethrin (Fastac* EC): 2.7 to 3.8 oz/A ECB and earworm, 3.2 to 3.9 looper; *PHI 1d succulent shelled or edible-podded, 21d dried, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.*

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with Bt kurstaki products (Dipel). Looper only.

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with Bt aizawai products (XenTari). Looper only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.* Succulent beans only.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 14d, REI 12h, Bee: L, Groups 16 & 28.*

carbaryl (Sevin XLR Plus): 0.5 to 1.5 qt/A; *PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 1A.* High rate for ECB. Not for CL.

chlorantraniliprole (Coragen): 5-7.5 oz/A soil at planting, 3.5-7.5 oz/A foliar; *PHI 1d, REI 4h, Bee: L, Group 28.* For ECB and CEW only.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; *PHI 7d edible-podded and succulent shelled, 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.*

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.* Earworm and looper only.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 3d fresh, REI 12h, Bee: H, Group 3A.* Not for ECB on dry beans.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; *PHI 7d snap; 21d dry, REI 24h, Bee: H, Group 3A.*

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 1d fresh at up to 1.5 pt/A, 3d for over 1.5 pt/A, 14d dry, REI 48h, Bee: H, Group 1A.*

methoxyfenozide (Intrepid 2F): 4 to 16 oz/A for ECB and CL, 10 to 16 oz/A for CEW; *PHI 7d, REI 4h, Bee: L, Group 18.* Use lower rates when plants are small or infestations are light.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

spinosad (Entrust SC^{OG}): 3 to 6 oz/A ECB, 4 to 6 oz/A CEW & looper; *PHI 3d, REI 4h, Bee: M, Group 5.*

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; *PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.*

■ Garden Springtails (*Bourletiella hortensis*)

Tiny (1/16") blue-grey insects that seem to hop like fleas. Important in the decomposition of dead plant matter. Occasionally, high populations feed on leaves of seedlings producing tiny pits in the leaf surfaces. Feeding resembles that of flea beetles. Plants may die of excessive water loss. Populations tend to be extreme in fields high in organic matter, with reduced-till systems, and with soils that crack when drying. Use clean cultivation and spot-treat areas where damage occurs. Most broad-spectrum insecticides registered for cutworms or leafhoppers will also control springtails.

ethoprop (Mocap* 15G): 13 to 20 lb/A for 36" row spacing or 0.9 to 1.4 lb/1,000 linear ft in a band 12 to 15" wide at planting; *REI 48h, Bee: H, Group 1B.* Incorporate in top 2" to 4" of soil. Do not use as seed furrow treatment. Treated beans may mature 1 to 2 weeks later. For snap and lima beans only.

■ Japanese Beetles (*Popillia japonica*)

Beetles migrate from turf or pastures starting in July and skeletonize leaves.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OC}): 1 to 2 lb/A (soil applications only); PHI 0d, REI 4h, Bee: M, Group M.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Mexican Bean Beetle (*Epilachna varivestis*)

Mexican bean beetle (MBB) most often builds up to damaging levels where snap beans are grown in the same or adjacent fields over successive years. Lima beans and dry beans are also susceptible, and MBB may feed in dry and edible-pod soybeans but are less likely to thrive on this host. Adults are copper-colored, oval, ladybeetles with black spots, 1/4" to 1/3" long. Eggs are orange to yellow in color, laid on the underside of leaves in clusters of 40 to 50. Larvae are yellow with rows of branched, black-tipped spines. The pupa is attached to the leaf, lacks spines, and is yellow to yellow-orange. Adults spend the winter in hedgerows and move into fields in June. Adults and larvae skeletonize leaves and may cause pod damage if numbers are high. There are 1 to 3 generations per year in New England, with newly emerging adults moving to the next succession planting of snap beans. A life cycle may be completed in 30 to 40 days during the summer. Populations are usually less abundant on early plantings and may not build to damaging levels until August. Prompt destruction of crop residue after harvest helps lower overwintering populations. Avoid continuous production of beans in the same or adjacent fields year after year. Annual releases of the larval parasitoid *Pediobius foveolatus*, timed to coincide with egg hatch, can help control beetle larvae. The wasp will not survive our winters, so must be re-released each year, but reproduces and moves into later plantings. Parasitized larvae serve as pupal cases for the wasp, remaining on the leaf and turning brown. Scout for MBB by searching plants for adults, eggs and larvae, and assessing damage. Treat when defoliation exceeds 20% pre-bloom or 10% during pod development. The presence of adults, eggs and larvae indicates potential for further damage. Be sure to get coverage of the lower leaf surfaces.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d dry, 1d fresh lima, REI 24h, Bee: H, Group 1B. Use on succulent green beans (snap) not permitted, except those grown for seed.

alpha-cypermethrin (Fastac* EC): 2.7 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, 21d dried, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OC}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 5 to 8 oz/A; PHI 7d edible-podded and succulent shelled, 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

dimethoate (Dimethoate 4EC): 8 to 16 oz/A; PHI 0d, REI 48h, Bee: H, Group 1B.

esfenvalerate (Asana* XL): 2.9 to 5.8 oz/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

kaolin (Surround WP^{OC}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. Use on seedlings and young plants, prior to pod set to avoid unsightly residue. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.60 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 12 to 48 oz/A; PHI 1d fresh at up to 1.5 pt/A, 3d for over 1.5 pt/A, 14d dry, REI 48h, Bee: H, Group 1A.

petroleum oil (Suffoil X^{OC}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

thiamethoxam (Cruiser 5FS): 1.28 oz/100 lb of seed; REI 12h, Bee: H, Group 4. Systemic seed treatment. Use standard slurry seed treatment equipment which provides uniform coverage of seed. For early-season protection from Mexican bean beetles.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

■ Potato Leafhopper (*Empoasca fabae*)

Adults are light yellow-green, 1/8" long, and wedge-shaped (wider at the head), while nymphs are bright green, flatter and wider than adults, and move sideways in a crab-like fashion. Adults lay eggs in stems and nymphs hatch and feed, passing through five instars before becoming adults. Presence of nymphs indicates an established population. Both adults and nymphs cause injury by injecting a toxin as they feed through piercing-sucking mouthparts. Potato leafhoppers (PLH) overwinter in Louisiana and vicinity and move north on storm fronts into the central states and then into New England on winds from the west. Arrival time varies with year and location, ranging from late May to late June. Low levels of leafhopper feeding can severely damage plants, especially at the seedling stage. Signs of injury begin with leaf veins turning pale, followed by yellowing or browning of areas of the leaf or leaf tips, which is known as 'hopperburn'. Leaves become brown, curl up, and die. Plants and roots may be stunted and yields reduced or lost. This process may take less than a week. PLH may also vector many viruses. Scout using sweep net or observing adults flying up when plants are shaken. Nymphs can be counted on undersides of leaves. Seedling beans should be treated if they have 2 adults per foot of row. From 3rd trifoliate leaf to bud stage, treat when PLH exceed 1 nymph/leaflet or 5 adults per foot of row, and repeat application in 7 to 10 days, if necessary. Be sure to treat lower leaf surfaces. In fields where a systemic seed treatment was used (e.g. Cruiser), foliar treatment should not be needed before bloom.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A. Edible-podded and succulent shelled peas and beans only.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d dry, 1d fresh lima, REI 24h, Bee: H, Group 1B. Use on succulent green beans (snap) not permitted, except those grown for seed.

alpha-cypermethrin (Fastac* EC): 2.7 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, 21d dried, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 1.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Succulent beans only.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 14d, REI 12h, Bee: L, Groups 16 & 28.

carbaryl (Sevin XLR Plus): 1 qt/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 7d edible-podded and succulent shelled, 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

dimethoate (Dimethoate 4EC): 8 to 16 oz/A; PHI 0d, REI 48h, Bee: H, Group 1B.

esfenvalerate (Asana* XL): 2.9 to 9.6 oz/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A foliar, 7 to 10.5 oz/A soil; PHI 7d foliar, 21d soil, REI 12h, Bee: H, Group 4A.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 0.25 to 0.5 lb/gall; PH 0d, REI 4h, Bee: L. Suppression and repellence only. Use on seedlings and young plants prior to pod set to avoid unsightly residue. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 12 to 48 oz/A; PHI 1d fresh at up to 1.5 pt/A, 3d for over 1.5 pt/A, 14d dry, REI 48h, Bee: H, Group 1A.

paraffinic oil (Organic JMS Stylet-Oil^{OG}): 0.75 to 1.5 gal/100 gal water; PHI 0d, REI 4h, Bee: L.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

thiamethoxam (Cruiser 5FS): 1.28 oz/100 lb of seed; REI 12h, Bee: H, Group 4. Systemic seed treatment. Use standard slurry seed treatment equipment which provides uniform coverage of seed. For early-season protection from leafhoppers.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

■ Seedcorn Maggot (*Delia platura*)

Seedcorn maggot larvae feed on the seeds and young seedlings of large-seeded crops such as corn, beans, and peas, as well as early seedlings of spinach, onions, brassicas, tomato, cucurbits, and other crops. They are the first maggot flies to become active in spring, about one to two weeks earlier than

onion or cabbage maggot. The adults look like small, gray houseflies with a slightly hump-backed shape. The seedcorn maggot larva is yellow-white, up to 1/4" long, legless, and has a wedge-shaped head. Pupae are oblong, brown, and about 4 to 5mm long. The seedcorn maggot fly overwinters in the pupal stage, in the soil where they fed in the fall. In early spring, the adults emerge and lay eggs on the soil surface. Growing degree days, using a base temperature of 39°F (4°C), can be used to predict peak emergence of the first generation (360°F GDD or 200°C GDD). Flies are attracted to volatiles released from freshly tilled soil, as well as to buried cover crop residues, rotting manure, compost, organic surface residues (as is found in reduced till), and organic amendments such as fish, soybean or cottonseed meal. Previously injured or diseased plants may also attract egg-laying. The eggs hatch within 2 to 4 days at soil temperatures of 60°F, and 7 to 9 days at 41-45°F. Larvae burrow downward in search of food and penetrate seeds as the seed coat splits open. Though there are 2 to 4 generations per year, it is the first generation that causes the most damage. The first symptoms are usually poor emergence of seeds or wilting of transplants that have lost their roots to feeding. Look for maggots and feeding tunnels inside seeds or stems to help distinguish damage from that of wireworm feeding or damping off. Crops that are planted in wet soil, or soil that is too cool to support quick germination and seedling growth, are especially susceptible to damage. Wait until soil conditions favor crop emergence and growth to help seeds and seedlings avoid or quickly recover from injury. Plant shallowly to promote rapid emergence. Where possible, incorporate cover crops, manure or compost several weeks before seeding. Put earliest plantings in lighter, well-drained, sandy soils that warm up fast. Among bean varieties, those with a dark seed coat sustain less injury than white varieties. Use row covers to exclude flies, except where flies may have fed in fall cover or vegetable crops and could emerge under the covers. Preventive chemical treatments include commercially applied systemic seed treatments and in-furrow applications of insecticides. Rescue treatments are not effective. If there is enough damage to warrant replanting, wait at least 5 days if maggots are a quarter inch long; if they are smaller than that, wait at least 10 days to make sure they have pupated and will not damage the new seeds.

chlorpyrifos (Lorsban* 4E): 2 pt/A in preplant broadcast application or 1.8 oz/1000 row feet at 30" row spacing; REI 24h, Bee: H, Group 1B. Preplant broadcast application incorporated into top 1" to 3" of soil or at plant T band application.

phorate (Thimet* 20-G): 4.5 to 7 oz/1000 ft of row; REI 48h, Bee: H, Group 1B. Apply granules in band over row and lightly incorporate. DO NOT place granules in direct contact with seed. Make sure granules are covered with soil. Do not feed treated crop residue to livestock.

thiamethoxam (Cruiser 5FS): 1.28 oz/100 lb of seed; REI 12h, Bee: H, Group 4. Systemic seed treatment. Use standard slurry seed treatment equipment which provides uniform coverage of seed. For early-season protection from seedcorn maggot.

■ Slugs

Damage appears as shredded foliage or fruit holes. Look for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours. Grow plants away from

moist, shaded habitats, use clean cultivation, control weeds, hand pick/crush slugs or scatter baits on the ground near infested plants. See the Cabbage section for more information on slugs.

iron phosphate (Sluggo: Slug and Snail Bait^{OG}): 20 to 44 lb/A; PHI 0d, REI 0h, Bee: L, Group 9B. Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; REI 12h, Bee: L. Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

■ Tarnished Plant Bug (*Lygus lineolaris*)

See Lettuce for information about tarnished plant bug.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d dry, 1d fresh lima, REI 24h, Bee: H, Group 1B. Use on succulent green beans (snap) not permitted, except those grown for seed.

alpha-cypermethrin (Fastac* EC): 2.7 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, 21d dried, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Succulent beans only.

carbaryl (Sevin XLR Plus): 1 to 1.5 qt/A; PHI 3d fresh, 21d dry, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 7d edible-podded and succulent shelled, 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OG}): 1 to 2 lb/A foliar; PHI 0d, REI 4h, Bee: M, Group M.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d fresh, 21d dry, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d fresh at up to 1.5 pt/A, 3d for over 1.5 pt/A, 14d dry, REI 48h, Bee: H, Group 1A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

sulfoxaflor (Transform WG): 1.5 to 2.25 oz/A; PHI 7d, REI 24h, Bee: H, Group 4C. Do not apply until after petal fall.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

Also known as Red Spider Mite. Outbreaks are favored by hot, dry weather and may be triggered by the use of broad-spectrum insecticides that kill the numerous natural enemies of mites. Spider mites affect dry, Lima and snap beans. Infestations begin on the lower portions of the plant and move upward. Watch for white speckling and bronzing on the upper surface of leaves (veins may remain green) and

grayish webbing on the undersurface around leaf veins. Use a 10X hand lens to see mites. Avoid early-season, broad-spectrum insecticide applications for other pests; use selective products whenever possible. Registered products for mites on beans may not provide complete control of the pest. With most miticides, use 2 applications approximately 5 to 7 days apart, to help control immature mites that were in the egg stage and protected during the first application. Coverage of the lower surface of the leaves is important. If further applications are needed, switch to an alternate resistance group to help prevent or delay resistance. For more information on TSSM management, see the Eggplant section.

abamectin (Agri-Mek SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Must be mixed with a non-ionic activator type wetting, spreading, and/or penetrating spray adjuvant. Do not use binder or sticker type adjuvant.

acequinocyl (Kanemite 15SC): 31 fl oz/A; PHI 7d, REI 12h, Bee: L, Group 20B. Succulent shelled bean only.

bifenazate (Acramite 50WS): 1 to 1.5 lbs/A; PHI 3d, REI 12h, Bee: M, Group un.

dimethoate (Dimethoate 4EC): 8 to 16 oz/A; PHI 0d, REI 48h, Bee: H, Group 1B.

fenpyroximate (Portal XLO): 2 pt/A; PHI 7d, REI 12h, Bee: L, Group 21A.

neem oil (Trilogy^{OG}): 0.5 to 2% solution in 25 to 100 gal water/A; PHI 0d, REI 4h, Bee: M, Group 18. Avoid mid-day applications and ensure good coverage.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

sodium tetraborohydrate decahydrate (Prev-AM Ultra): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

sulfur (Microthiol Dispers^{OG}): 3 to 10 lb/A; REI 24h, Bee: L, No IRAC classification. Check for sulfur sensitivity prior to treating the whole field; some varieties may be injured by sulfur.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d fresh, 21d dry, REI 12h, Bee: H, Group 3A.

WEED CONTROL

Weeds may develop quickly because beans are slow to establish a canopy. Use a tine-weeder or a rotary hoe if there is not too much field residue for pre-emergent mechanical weed control. Do not cultivate when the beans are starting to emerge as seedlings are very fragile and can easily snap. Cultivate 3-4 times when beans are 2-3 inches tall until canopy closure. Bean taproots are easily torn from the ground during imprecise mechanical cultivation. To minimize damage to plants, do not cultivate when leaves are wet or just after they have flowered.

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107 for information on the use of these herbicides.

glyphosate (Roundup Power Max): *REI 12h, Group 9.* Rate based on target weed species. See label for info.

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Snap and lima only. Use 2-4 pts/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Preplant Incorporated/Preemergence to Weeds

dimethenamid (Outlook): *PHI 70d, REI 12h, Group 15.* Dry beans only (including small whites, navy, black turtle soup, pink, pinto, great northern, red Mexican, red kidney, cranberry, and lentils). May be applied preplant surface, preplant incorporated, preemergence, or early postemergence (1st to 3rd trifoliolate). As a single application, apply 12 to 18 oz/A on coarse-textured soil and 14 to 21 oz/A on finer textured soils. A split application may be used (10 to 14 oz/A per application, not to exceed 21 oz/A total). Allow 14 days between applications. Will not control emerged weeds. Check with seed supplier for potential varietal susceptibility to injury.

EPTC (Eptam 7E): *REI 12h, Group 8.* Do not use on lima beans. Apply 2.25 to 4.5 pt/A prior to planting, incorporate immediately to a depth of 2" to 4". Soil surface must be dry. For nutsedge, incorporate 4" to 6" deep. Do not exceed 3.5 pt/A on green beans grown on coarse-textured soil.

ethalfluralin (Sonalan HFP): *REI 24h, Group 3.* Dry beans only. Incorporate 1.5 to 3 pt/A (rate based on soil texture, see label) prior to planting to a depth of 2" to 3". Higher rates are registered for control of nightshade and ground cherry (3 to 4.5 pt/A); see label for details.

pendimethalin (Prowl H₂O): *REI 24h, Group 3.* Apply 2 to 3 pt/A preplant and incorporate into the soil 2" to 3". Rate based on soil texture; see label for details. Do not apply after seeding.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.* Apply either preplant incorporated or to the soil surface just after seeding. See label for specific rates on different soil types and organic matter content (1 to 2 pt/A). May be tank mixed with either EPTC or trifluralin. Follow precautions on all labels when tank mixing. NOTE: Crop injury has been noted on both snap beans and lima beans from the use of metolachlor. Use of tank mixes, where the rate of metolachlor could be lowered, will decrease the likelihood of crop injury.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Rate based on soil texture and crop, see label for details. Incorporate 1 to 2 pt/A before planting. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation.

■ Preemergence to Weeds - At Planting

clomazone (Command 3ME): *REI 12h, Group 13.* Snap beans only. Apply 0.4 to 0.67 pt/A to the soil surface after seeding but before crop emergence. Will control annual grasses and many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Combining with Dual Magnum will also control yellow nutsedge and pigweed. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for replanting restrictions.

halosulfuron (Sanda): *PHI 30d, REI 12h, Group 2.* Rates vary based on crop and application timing (0.5 to 1 oz/A for succulent beans (snap and lima) and 0.5 to 2/3 oz/A for dry beans). Use the lower rate on lighter textured soils. Can cause temporary stunting. Heavy rains following application will increase the potential for crop injury. Use of organophosphates can increase crop injury from halosulfuron. See the label for other precautions and a list of weeds controlled.

Preemergence: Can be applied as a preemergence after seeding and before crop emergence.

Postemergence: Use postemergence after dry beans reach 1-3 trifoliolate leaf stage or snap/lima reach 2-4 trifoliolate leaf stage, but before the crop flowers. Treatments applied when beans are younger increase the risk of crop injury. Application after the third trifoliolate leaf increases the risk of split set. Add a nonionic surfactant at a rate of 0.25% v:v (1 qt/100 gal) spray solution. Will control yellow nutsedge and many broadleaf weeds. Will not control lambsquarters postemergence.

■ Postemergence to Weeds

bentazon (Basagran): *PHI 30d, REI 48h, Group 6.* Used postemergence on actively growing weeds. Rate varies based on weed species targeted (1 to 2 pt/A). See label for info. Apply after the first trifoliolate leaf (three leaflets) has fully expanded to avoid crop damage. An effective treatment in an emergency situation to control certain broadleaf weeds and fairly effective against yellow nutsedge when 4" to 6" tall.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

■ Postemergence Grass herbicides

clethodim (Select Max): *PHI 30d dry beans, PHI 21d for snap beans, REI 24h, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. For dry beans, multiple applications permitted of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. For snap

beans, only a single application of 9 to 16 oz/A is permitted. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluazifop (Fusilade DX): PHI 60d, REI 12h, Group 1. Dry beans only. For grass weed control only. Apply up to 24 oz/A. See label to select rate based on grasses targeted for control. Allow for minimum 14-days between applications, and not to exceed 48 oz/A per year. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

quizalofop (Assure II): PHI 30d dry beans, PHI 15d snap beans, REI 12h, Group 1. Apply to actively growing grasses. Rate based on target weed species, see label for grass growth stage and rate selection. Multiple applications permitted. Allow at least 7 days between applications. Do not exceed 24 oz/A per season for dry beans and do not exceed 14 oz/A per season for snap beans. Apply with either crop oil concentrate or non-ionic surfactant. Do not apply when crop or weeds are under drought stress.

sethoxydim (Poast): PHI 30d dry beans, PHI 15d snap beans, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 4 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

BEET AND SWISS CHARD

Beets (*Beta vulgaris* var. *crassa*) and Swiss chard (*Beta vulgaris* var. *cicla*) are members of the *Chenopodiaceae* family, along with lambquarters. Both are cool-season crops that can tolerate frosts and light freezes. Chard is raised for its large leaves and stems, and beets are raised both for greens and roots. The best quality is obtained when beets are grown under conditions of good sunlight and cool temperatures (50°-65°F). The higher temperatures of summer can cause “zoning” in beets, e.g. alternating light and dark rings and lower sugar content. Beets grow best in deep, friable, well-drained, sandy loams to silt loams. High organic content in the soil is desirable and will help maintain

an adequate moisture supply. Organic matter should be well decomposed to avoid scab problems with beets.

Types and Varieties

Beet and Chard Varieties	
Bunching Spring Beets Kestrel Boro Red Ace Red Cloud Detroit Supreme - OP Early Wonder - OP	Summer and Fall Beets Kestrel Boro Red Ace Red Cloud Moneta (monogerm) Pacemaker III
Beet Greens Bull's Blood - OP Early Wonder Tall Top - OP Fresh Pak	Specialty Beets Cylindra - cylindrical Taunus - cylindrical Boldor - yellow Touchstone Gold - yellow Chioggia Guardsmark - OP, striped interior
Chard Varieties Bright Lights - multicolored mix Fordhook Giant - OP Large White Ribbed - OP Silverado Ruby Red	
Codes: OP: open-pollinated.	

Soil Fertility

Apply lime according to soil test to maintain soil pH at 6.5-6.8. In alkaline soils, the chance of boron and manganese deficiency is increased. High levels of nitrogen in relation to phosphorus and potassium will result in heavy leaf production with poor root development. Beets have a high potassium requirement. Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Beets are subject to boron deficiency; young leaves fail to develop normally, turn black and die. This is accompanied by internal breakdown, canker, or dry rot of the root. To prevent deficiency, apply 2 lb B per acre (10 lb Solubor, 20 lb borax) with the broadcast fertilizer application. Make sure that the next crop in the rotation schedule is not sensitive to boron residue.

Planting

Seed is planted 0.25"-0.5" deep in rows 18"-24" apart aiming at a density of 15-30 plants per foot. For most beet varieties (except monogerm varieties) each seed ball contains up to 6 seeds, so thinning is required. Both beets and chard may be transplanted for an earlier spring crop.

Plant Nutrient Recommendation According to Soil Test Results for Beet and Swiss Chard

BEET AND SWISS CHARD	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P2O5 per acre				Potassium (K) Lbs K2O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate	75-100	150	100	50	0	300	150	75-100	0
Sidedress after 1st or 2nd cutting	30	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	105-130	150	100	50	0	300	150	75-100	0

Harvest and Storage

Swiss chard: Chard does not bolt or go to seed as readily as spinach and, therefore, is a good summer substitute. Many successive harvests can be made from one planting. Chard is frost resistant and can be harvested well after the first killing frost. Once harvested, chard can be kept for 1-2 weeks at 32°F and 95-98% relative humidity.

Beet: Bunched beets can be kept for 10-14 days at 32°F and 98% relative humidity. Topped beets can be stored for 3-6 months or more at 33°-36°F and 98% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Leaf Spots and Blights (*Alternaria*, *Ascochyta*, *Cercospora*, Powdery Mildew)

Plant resistant cultivars where available. Use cultural practices that minimize periods of leaf wetness such as plant spacing, planting in the direction of prevailing winds, and avoiding overhead irrigation. Promptly incorporate plant debris after harvest to speed decomposition.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11*. Applications of Quadris to leafy vegetables may cause phytotoxicity; proceed with caution with regards to tank mixes and adjuvants.

copper hydroxide (Kocide 3000): 0.75 to 2.0 lb/A. Beet only; *PHI 0d, REI 48h, Group M1*. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

penthiopyrad (Fontelis): 14.0 to 24.0 fl oz/A; *PHI 3d, REI 12h, Group 7*.

propiconazole (Tilt): 4.0 fl oz/A; *PHI 14d, REI 12h, Group 3*.

pyraclostrobin (Cabrio): 12 to 16 oz/A; *PHI 0d, REI 12h, Group 11*. Do not alternate with Quadris or Flint.

Swinglea glutinosa extract (EcoSwing⁰⁶): 1.5 to 2 pts/A; *PHI 0d, REI 4h*. Labeled for *Alternaria* leaf spot and powdery mildew.

trifloxystrobin (Flint): 2 to 3 oz/A; *PHI 7d, REI 12h, Group 11*. Do not alternate with other Group 11 fungicides.

■ Downy Mildew (*Peronospora farinosa* f. *sp. betae*)

Plant resistant cultivars where available. Use cultural practices that minimize periods of leaf wetness such as plant spacing, planting in the direction of prevailing winds, and avoiding overhead irrigation. Promptly incorporate plant debris after harvest to speed decomposition.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; *PHI 0d, REI 12 h, Groups 45 and 40*. Not for beets.

***Bacillus amyloliquefaciens* F727 (Stargus⁰⁶):** 2 to 4 qt/A; *PHI 0d, REI 4h, Group 44*. Apply preventatively in a minimum of 50 gallons of water/A.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; *PHI 2d, REI 12h, Group 43*. Must be tank mixed with a fungicide with a different mode of action. Not for beets.

oxathiapiprolin (Orondis Ultra A): 2.0-4.8 fl.oz/A; *PHI 0d, REI 4h, Group 49*. Begin foliar application prior to disease development. Not for beets.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that heat or moisture stressed. Do not apply directly to copper treated plants within 20-day interval to avoid plant injury.

pyraclostrobin (Cabrio): 12 to 16 oz/A; *PHI 0d, REI 12h, Group 11*. Do not alternate with Quadris or Flint. Not for beets.

■ Seed Decay

Plant on well-drained soil. Buy treated seeds. Do not use treated seed for food, feed or oil purposes.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/00 lb seed; *REI 12h, Group 12*. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lb seed; *REI 48h, Group 4*. For *Pythium* damping-off protection.

thiram (Thiram 42 S): 8.0 lb/100 lb seed; *REI 12h, Group M3*. Not for Swiss chard.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids (*Myzus persicae* or *Aphis fabae*)

Aphids may include green peach aphid (*Myzus persicae*) or bean aphid (*Aphis fabae*). See Peppers for more information about green peach aphid. Bean aphid favors plants in the *Chenopodiaceae* family (beets, chard, spinach, sugar beet) and feeds on a wide range of weeds (e.g. curly dock, lambsquarters, shephardspurse) as well as many other vegetables, but only rarely builds to damaging levels. Bean aphid adults and nymphs are dark olive-green to dull-black in color, with dark legs. They feed in young tissue of actively growing plants; high numbers can cause leaf curling and stunting. In general, using selective products for other pests will conserve natural enemies of aphids and prevent outbreaks.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A. Swiss chard only.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A beets, 2.2 to 3.8 oz/A chard; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A on beets, 2.1 to 6.4 oz/A on Swiss chard; PHI 1d beets, 7d Swiss chard, REI 12h, Bee: H, Group 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Green peach aphid only. Swiss chard only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For control of green peach and suppression of potato aphid only. Swiss chard only.

dimethoate (Dimethoate 4EC): 8 oz/A; PHI 14d, REI 48h, Bee: H, Group 1B. Swiss chard only.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 7d foliar, 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. For Swiss chard only.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 3d beets, PHI 0d chard, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A for foliar application, 21 to 28 oz/A for soil application (Swiss chard only); PHI 1d foliar, 21d soil, REI 4h, Bee: L, Group 4D.

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

malathion (Malathion 57 EC): 1.5 to 2 pt/A beets, 1 to 1.6 pt/A Swiss chard; PHI 7d beets, 14d Swiss chard, REI 12h, Bee: H, Group 1B.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Swiss chard only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pymetrozine (Fulfill): 2.75 oz/A; PHI 7d, REI 12h, Bee: L, Group 9A. Swiss chard only.

spirotetramat (Movento): 4 to 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility. Swiss chard only.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A. Foliar applications only; PHI 3d, REI 12h, Bee: H, Group 4C.

sulfoxaflor (Transform WG): 1.5 to 2.25 oz/A. Beets only; PHI 7d, REI 24h, Bees: H, Group 4C.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 12 oz/A on beets, 5 to 11 oz/A on Swiss chard; PHI 30d Swiss chard, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment.

tolfenpyrad (Torac): 17 to 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A. Except lettuce aphids. Swiss chard only.

■ Blister Beetles (*Epicauta funebris* and *E. vittata*)

The margined blister beetle, *Epicauta funebris* and the striped blister beetle, *Epicauta vittata*, are the most common blister beetles in the Northeast. These beetles have also been called the "old fashioned potato beetle". They attack chard, beet and spinach along with other vegetable crops including bean, eggplant, pepper, potato, sweet potato, tomato, and sometimes brassicas. They are very attracted to pigweed and other *Amaranthus* spp., and also feed in alfalfa and clover. Adults are soft-bodied, slender, long-legged beetles, about 5/8" long. The section of the body between the head and the wings is distinctly narrower, giving the impression that the insect has a neck. The egg, larval and pupal stages occur in the soil, and grasshopper eggs are a favored food for larvae. There is one generation per year in the Northeast, and beetles overwinter as larvae in the soil. Margined blister beetles are dark gray or black with light-gray lines along the margins of the wings. They feed primarily on flowers and blossoms of plants, but may also feed on the leaves. Striped blister beetles are yellow to rusty orange with 2 black spots on the head and 2 black stripes dorsally on the thorax and the wings. They are mainly foliage feeders and often appear in large swarms, sometimes quite suddenly, and concentrate in one particular area of a field where they can cause significant feeding damage. Blister beetles contain an oily, caustic substance called cantharidin that protects them from natural enemies. In humans, it causes temporary blisters on the skin; in livestock, especially horses, consuming cantharidin causes severe injury and contamination of hay with blister beetles is a serious concern. Where local swarms occur in a crop, a single spot spray with a broad-spectrum insecticide registered for flea beetles on these crops effectively controls blister beetles.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Cabbage Maggot

Floating row covers can be used. No insecticides currently registered. For more information see cabbage maggot in the cabbage section.

■ Flea Beetles

Several species of flea beetles feed on beets and chard. Most have a wide host range and tend to be moving among various crops and weeds. Most are black. The species that feed especially on brassicas do not tend to feed on beets or Swiss chard.

Damage (small ‘shot holes’) is most common on seedlings but can occur on older leaves as well.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A beets, 2.2 to 3.8 oz/A chard; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.*

beta-cyfluthrin (Baythroid* XL): 2.4 to 3.2 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.* Swiss chard only.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A on beets, 2.1 to 6.4 oz/A on Swiss chard; *PHI 1d beets, 7d Swiss chard, REI 12h, Bee: H, Group 3A.*

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; *PHI 7d beets, 14d Swiss chard, REI 12h, Bee: H, Group 1A.*

dinotefuran (Venom): 1 to 3 oz/A foliar. Swiss chard only; *PHI 7d, REI 12h, Bee: H, Group 4A.*

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A; *PHI 21d, REI 12h, Bee: H, Group 4A.* Soil applications only. Beets only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

thiamethoxam (Actara): 1.5 to 3 oz/A; *PHI 7d, REI 12h, Bee: H, Group 4A.*

thiamethoxam (Platinum): 5 to 12 oz/A on beets, 5 to 11 oz/A on Swiss chard; *REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone at planting/transplanting.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* For Swiss chard only.

■ Leafminers (*Pegomya hyoscyami* and *P. betae*)

Spinach leafminer (*Pegomya hyoscyami*) and beet leafminer (*P. betae*) attack crops in the family *Chenopodiaceae* (chard, beet, and spinach). Spinach leafminer may also cause damage in Solanaceous crops. In beets, leafminer is only a pest if the leaves are marketed or pressure is high enough to reduce root growth. The fly overwinters as a pupa in the soil and the small (5 to 7 mm) gray hairy adult flies emerge from late-April to mid-May. The two species are similar, but beet leafminer adults are slightly larger and darker, and beet leafminers prefer laying eggs on beet leaves. Female flies lay oblong white eggs (<1mm) in neat clusters on the underside of the leaves. Eggs hatch in 3 to 6 days. The larva burrows between the upper and lower epidermis of the leaf and feeds, creating a slender, winding ‘mine’ or tunnel. This expands into large blotches of translucent, dead tissue across the leaf, with a white maggot inside. Damaged leaves are unmarketable. When fully grown, maggots usually drop into the soil to pupate. The entire life cycle takes 30 to 40 days and there are 3 to 4 generations per season, with peak activity periods in mid to late-May, late-June and mid-August. Leafminer is most important as an early spring pest, but when populations are high, overlapping generations can cause continuous season-long damage to succession-planted spinach, beets and chard. After August, pupae enter overwintering phase

and won’t emerge until next spring. A commercially available biological control is the tiny wasp parasitoid, *Diglyphus isaea*, which is most often used against *Liriomyza* leafminers (see Celery section) but has also been known to control leafminers in chard. They work best in warm weather.

For prevention, rotate beet, chard and spinach to new fields in the spring and during the growing season. Avoid spring plantings near tunnels where winter greens were grown. Control weed hosts including lambsquarter, nightshade, chickweed and plantain. Row covers protect the crop by excluding flies, but scout for eggs on transplants before covering. Scout spring transplants in the greenhouse and in the field for eggs, which are easy to spot on the underside of leaves. Treat when eggs are first observed. If tunnels and eggs are present, treat to prevent further damage. Scout again to determine if a second treatment is needed in 7 to 10 days. Use an adjuvant and ensure coverage of lower leaf surface. Some systemic insecticides are registered that may be applied to transplants or to the soil. Among organic products, spinosad has demonstrated efficacy when applied before egg hatch. Note that some products are labeled only for Swiss chard.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant. Swiss chard only.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.*

chlorantraniliprole (Coragen): 5.0 to 7.5 oz/A; *PHI 1d, REI 4h, Bee: L, Group 28.* May be applied to soil at planting, through drip chemigation and as a foliar spray. Swiss chard only.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.* Swiss chard only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; *PHI 0d, REI 4h, Bee: H, Group 28.* For soil applications at planting. Swiss chard only.

cyromazine (Trigard): 2.66 dry oz/A; *PHI 7d, REI 12h, Bee: M, Group 17.* Swiss chard only.

dimethoate (Dimethoate 4EC): 8 oz/A; *PHI 14d, REI 48h, Bee: H, Group 1B.* Swiss chard only.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 7d foliar, 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. Swiss chard only.

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Leafminer suppression on Swiss chard only.

***Isaria fumosorosea* Apopka Strain 97 (PFR-97 20% WDG^{OG}):** 1 to 2 lb/A foliar; *PHI 0d, REI 4h, Bee: M, Group M.*

paraffinic oil (Organic JMS Stylet-Oil^{OG}): 0.75 to 1.5 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Beets only.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Swiss chard only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

spinetoram (Radiant SC): 6 to 10 oz/A; *PHI 1d Swiss chard, 3d beet greens, REI 4h, Bee: M, Group 5.*

spinosad (Entrust SC^{OG}): 4.5 to 10 oz/A beets, 6 to 10 oz/A Swiss chard; *PHI 3d beets, 1d Swiss chard, REI 4h, Bee: M, Group 5.* Control may be improved with the addition of an adjuvant. Do not apply to Swiss chard seedlings intended for transplant.

thiamethoxam (Platinum): 5 to 12 oz/A on beets, 5 to 11 oz/A on Swiss chard; *PHI 30d Swiss chard, REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. Suppression only and only on Swiss chard.

■ Slugs

Damage appears as shredded foliage. Look for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours. Grow plants away from moist, shaded habitats, use clean cultivation, control weeds, hand pick slugs or scatter baits on the ground near infested plants. See the Cabbage section for more information on slugs.

iron phosphate (Sluggo: Slug and Snail Bait^{OG}): 20 to 44 lb/A; *PHI 0d, REI 0h, Bee: L, Group 9B.* Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metolachlor (Deadline Bullets): 20 to 40 lb/A; *REI 12h, Bee: L.* Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

cycloate (Ro-Neet): *REI 48h, Group 8.* Beets only. Not for use in Vermont, Connecticut or Rhode Island. Preplant incorporated. Apply 1/2 to 2/3 gal/A 10 to 50 gallons of water per acre. Must be immediately incorporated into the soil to a depth of 2-3" to prevent loss of the herbicide. Use on mineral soils ONLY. Use lower rate on sandy soils. Use

higher dosage rate on heavier soils. Works by interfering with seed germination and seedling development. Will not control existing weeds.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.*

MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. This is a restricted label available only to growers who register through the website www.farmassist.com and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 30d, REI 24h, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

clopyralid (Stinger): *PHI 30d, REI 12h, Group 4.* Beets only. For postemergence control of weeds in the composite and legume families. Apply when beets are in the 2- to 8-leaf stage and weeds are young and actively growing. Common annuals include galinsoga, ragweed, pineappleweed, clover, and vetch. Perennial weeds controlled include Canada thistle, goldenrod species, aster species, and mugwort (wild chrysanthemum). Stinger is very effective on small seedling annual and emerging perennial weeds less than 2" to 4" tall, but is less effective and takes longer to work when weeds are larger. Use 0.25 pt/A (4 oz/A) to control annual weeds less than 2" tall. Use up to 0.5 pt/A (8 oz/A) to control larger annual weeds, and to suppress perennial weeds. Spray additives are not needed or required by the label and are not recommended. Stinger is a postemergence herbicide with some soil residual activity. Observe replant restrictions on the label or injury may occur from herbicide carryover.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will

cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 60d for beets, PHI 30d for chard, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. For beets, maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 5 pt/A per year. For chard, maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

CABBAGE, BROCCOLI, CAULIFLOWER, AND OTHER BRASSICA CROPS

The term “cole crops” refers to waxy-leaved brassicas of European origin, of the species *Brassica oleraceae*. Cabbage, broccoli and cauliflower and other brassica crops are hardy crops that are well adapted to New England. Plants maturing under cool weather conditions are of especially high quality. This diverse family has similar cultural requirements, diseases and pests.

Types and Varieties

Cabbage is the most widely grown and easily cultivated of the cole crops. Some varieties mature in as few as 60 days or as many as 120 days from transplanting. The early and mid-season varieties are generally better suited for fresh market sales where small heads of 3-4 lb are desired.

Cauliflower is more difficult to grow than other brassica crops. Common problems include failure to head properly and poor curd quality. For successful production of cauliflower, a fertile, moist soil relatively high in organic matter and nitrogen is needed. Buttoning is the premature formation of the head, when the leaves are not large enough to produce a head of marketable size. Conditions that reduce the vigor of the plant and retard vegetative growth, such as cold temperatures at transplanting and any of a number of other stresses appear to encourage buttoning. Cauliflower varieties range in maturity from 55 to 95 days.

Broccoli is not as exacting in its requirements as cauliflower, however, it must be harvested promptly to avoid flowering. The earliest spring plantings often experience buttoning. In summer months, temperatures over 85°F during the critical period when the head begins to form can result in poor head quality. In Southern New England, broccoli is best grown as a fall crop. Broccoli varieties range in maturity from 55 to 75 days.

Brussels sprouts are generally a long season crop grown for harvest in the fall. Brussels sprouts should be harvested when they are round, firm, tight and of good color.

Kale is cold-hardy and grows best as a fall crop when grown for full-size leaves, but can be succession-planted all season. Kale is also commonly grown as a component of salad mix

(see Salad Mix Section). The flavor of the leaves is improved after a light frost.

Kohlrabi looks like a turnip growing on the top of the ground with sprouting leaves over the surface. It must be harvested when 1-1/2"-3" in diameter or it will become tough and stringy.

Chinese cabbage (*Brassica napa*), **mustard** (*Brassica juncea*) and **bok choy** (*Brassica rapa* var. *chinensis*), are grown as salad or braising greens or as a heading crop. They have non-waxy leaves and most are Asian in origin. See Salad Mix section for more details on production of salad mix. Crops in this group are more susceptible to damage from flea beetles, but tend to be less attractive to caterpillars than waxy cole crops. When grown as heading crops, these should be direct seeded from early May to mid-July depending on intended harvest date and location in New England. Chinese cabbage is especially sensitive to bolting in response to stress or cold. Nitrogen management for Chinese cabbage should differ slightly from other cole crops (see Soil Fertility, below).

Many other brassica greens, such as mizuna, mibuna, tatsoi, komatsuna, arugula, and mustard are usually direct seeded. Some varieties are prone to premature flowering, which is enhanced by cold temperatures in the spring. Transplanting, which is less common than direct seeding, can also increase premature flowering in the spring due to increased plant stress. Plant populations vary tremendously and should be geared toward the intended harvest age and size.

Brassica Crop Varieties	
Broccoli - Spring Belstar Castle Dome Green Magic - DM	Cabbage - Early Caraflex (pointed) Fast Vantage Red Express (red) Tendersweet - Y Tiara
Broccoli - Summer/Fall Arcadia - DM Diplomat - DM Gypsy - DM Imperial Marathon - DM	Cabbage - Midseason Capture - Y, BR Early Thunder - Y, BR Red Jewel (red) - TB
Cauliflower Amazing Freemont Snow Crown Skywalker Graffiti (purple) Cheddar (yellow)	Cabbage - Late Season / Storage Passat - Y, T Report - Y, TB, BR, CR SuperRed 115 (red) - Y Storage #4 - Y, TB Vantage Point - Y Ruby Perfection (red)
Brussels Sprouts Diablo Oliver Nautic	Cabbage - Savoy Alcosa - DM Deaddon (tinged red) - Y Famosa - TB, DM
Cabbage - Chinese Blues (Napa type) Greenwich (Michihili type) Jade Pagoda (Michihili type) Rubicon (Napa type)	Kohlrabi Konan Kolibri (purple) Kossack (giant)
Cabbage - PakChoi Mei Qing Choi Joi Choi	Kale Winterbor Red Russian Lacinato
Resistant or tolerant to: BR: black rot, CR: clubroot, DM: downy mildew, TB: tipburn, Y: yellows	

Soil Fertility

Apply lime according to soil test to maintain soil pH at 6.5 to 6.8. Maintain a high level of calcium to minimize tip burn.

The best method to apply a small amount of boron is as an additive to the fertilizer. For example, if the level of boron in the soil is low, apply 3 lb of boron (15 lb Solubor, or 30 lb Borax per acre before planting broccoli and cauliflower, and 2 lb/A for cabbage. See Tables 6 and 6a, page 14.

For **Chinese cabbage**, pepper spot can develop on the stalks of the plants as a result of excess nitrate uptake. Apply only 50 lb of actual nitrogen at planting and sidedress additional nitrogen at diminishing rates as the plant nears harvest maturity, for a total of 150 lb/A. Foliar or drip scheduled at 6-8 lb per week may be the most practical.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

If using transplants, use of a liquid starter fertilizer at planting time is beneficial, especially with cool soil conditions. Use a high phosphorus starter fertilizer mixed at a rate of 3 lb per 50 gallons of water. Apply 8 fluid ounces (1 cup) per transplant.

Planting

Early plantings of cabbage and other cole crops are generally made by setting out transplants grown in greenhouses or cold frames. Transplants should be 4-6 weeks old at field setting; and, for cauliflower and broccoli, transplants should be produced in greenhouses with a minimum temperature of 55°F. Excessive cold, transplant stress, inadequate fertility or other sources of stress in early stages can cause cole crops to button, or to go to seed without heading. Transplants with thick stems are likely to head prematurely or button. Midseason and late plantings can be transplanted or direct seeded. If cabbage, broccoli or cauliflower are direct seeded, 2-3 weeks should be added to the number of days to maturity.

Generally, coarse-textured soils (sands, sandy loams, etc.) are favored for early plantings because they can be worked earlier in the spring and will warm up faster. These soils are also less likely to become waterlogged under rainy spring conditions. Finer textured soils which have a greater water holding capacity can frequently be used to advantage for producing later crops.

Cabbage grown for fresh market should be planted to stand 12"-15" apart within rows and 24"-36" between rows.

With most early or midseason varieties the closer spacing will give larger yields and smaller heads, which can be a more desirable size for fresh markets. Where direct seeding is used, seeding depth is 1/2"-3/4". One-half to 1 lb of seed will be required per acre (0.125-0.25 oz per 100 feet of row) depending on cultivar, seed size, and spacing. Thin seedlings to desired stand when plants are 2"-4" tall. Do not allow plants to become crowded.

Cauliflower should be planted to stand 15"-18" apart within rows and 30"-36" between rows. **Broccoli** should be spaced according to market needs. Large single heads can be achieved by a 15"-18" spacing. Three-head bunches require 5"-6" heads with small stalks; plant double row beds with 36" between beds and 10"-12" between rows within beds. Space 6"-9" between plants, depending on cultivar. Early varieties usually require closer spacing. Southern grown plants can be purchased for transplants, but insect and disease problems often accompany them. If purchasing bare root transplants from nurseries, plant soon upon receipt. Field-grown cabbage transplants, once pulled, should not be stored for longer than 9 days at 32°F (0°C) or 5 days at 66°F (19°C) prior to planting in the field. Cauliflower and broccoli can be direct seeded to stand, with precision type planters. Raised beds of 4" are recommended. For cauliflower this will require about 4 oz seed per acre (0.0625 oz per 100 feet of row); for broccoli about 0.5-1 lb/acre (0.125-0.25 oz per 100 feet of row).

Brussels Sprouts are most commonly grown from transplants. In general, they are grown as a long season crop grown for fall harvest. Cool weather and light frosts prior to harvest increase quality. Rows are typically spaced 3' apart with 15" spacing within the row. Plants can be topped in early September to improve sprout size uniformity if harvesting entire stalks. Trimming foliage from the lower 1/2-2/3 of the plant will allow more light to reach the developing sprouts, as well as increase air circulation both of which increase sprout quality.

Kale can be successfully grown from direct seeding or from transplants. For direct seeding, sow seed at 3-4 lb per acre in rows spaced 16"-36" apart. Thin to 4"-5" apart in the row. Transplants are set in rows 16"-36" apart and 6"-12" apart in the row. Use wider between-row and in-row spacing for multiple hand harvests by stripping leaves.

Kohlrabi may be grown for spring crops by transplants. Transplant into the field at the same time as broccoli or cabbage. Fall crops can be established by direct seeding between June 25 and July 15. Seed open-pollinated varieties at

Plant Nutrient Recommendation According to Soil Test Results for Cabbage, Broccoli, Cauliflower, and Other Brassica Crops

CABBAGE, BROCCOLI, CAULIFLOWER, AND OTHER BRASSICA CROPS	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O ₅ per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	100	150	100	50	0	175	125	50	0
Sidedress 4 weeks after transplant	60*	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	160	150	100	50	0	175	125	50	0

*Cauliflower apply 30 lbs /A.

Crops

the rate of 2-3 lb per acre and thin to 6"-8" between plants in the row. Precision-seed hybrid varieties. Set transplants July 20 to August 15. Space rows 18"-24" apart.

Irrigation

The availability of water can be critical for successful production. Adequate soil water must be maintained during seedling or transplant establishment and the period of rapid vegetative growth that follows. This is extremely critical prior to head initiation for cabbage, since excessive water applied after cabbage heads have formed can result in split heads. When harvest periods of broccoli and cauliflower occur during times of high temperatures, light irrigation (0.33"-0.5") can be used to cool plants and help maintain quality.

Harvest and Storage

Cabbage. Harvest as soon as the head has reached full size for the cultivar grown. Many varieties will stand in the field for considerable periods of time after heading without serious deterioration. Harvest should not be delayed unnecessarily as plants become more susceptible to disease and to splitting.

Cauliflower. In order to produce the attractive white curd in most cauliflower varieties, it is necessary to blanch the head. When the head is 2"-3" in diameter, gather the large outer leaves loosely over the head and tie with twine or rubber bands. Tie every two to three days with different colored bands to help coordinate harvest dates. Hot, humid, rainy weather after tying can result in a rotting curd. The head should be ready to harvest 5-15 days after tying. Harvest when head is compact, clear white and about 6" in diameter.

Broccoli is harvested when heads are dense, 3"-6" in diameter and before individual flower buds are distinguishable or yellow flowers can be seen. Cut 8"-10" of stem with the head. Broccoli should be cooled as rapidly as possible and stored under cool conditions after harvest to slow down flower development. Side heads develop rapidly following removal of the terminal head, unless the cultivar used is a nonsprouting type. Harvesting may continue for several weeks.

Brussels Sprouts should be harvested when sprouts are firm and are of the desired size for market. Sprouts can be harvested sequentially, working up the stalk as the season progresses, or entire stalks can be cut and marketed whole.

Kale and collards may be harvested by cutting off entire plants near ground level. Whole plants are then bunched, or lower leaves may be stripped from plants and either bunched or packed individually. Multiple harvests are possible. Because of their perishability, kale and collards should be held as close to 32°F as possible. At this temperature, they can be held for 10-14 days. Relative humidity of at least 95% is desirable to prevent wilting. Air circulation should be adequate to remove heat of respiration, but excessive air circulation will speed transpiration and wilting.

Kohlrabi. The targeted harvest stage is when stems are full sized but before they begin to split.

Many brassica crops are very sensitive to ethylene, and may yellow upon exposure to low levels of ethylene. These crops should be stored as close to 32°F as possible without freezing, at high relative humidity. Expected storage life varies widely.

Cabbage, Broccoli, Cauliflower, and Other Brassica Crops 141

Consult USDA Handbook 66: The commercial storage of fruits, vegetables and florist and nursery stocks, for crop-specific information.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ *Alternaria* Damping Off

Buy seed certified as disease-free or treat with hot water at 122°F for 25 minutes (see Hot Water Treatment of Seed, page 78). Cole crop seed is susceptible to seed vigor loss from hot water treatment. Seed should be treated as close to planting as possible.

■ *Alternaria* Leaf Spot and Head Rot

Leaf spot and head rot are caused by at least three species of *Alternaria*, and may be seed-borne. Start with certified disease-free seed. Destroy diseased crop residues after harvest. Differences in cultivar susceptibility exist. Avoid overhead irrigation to prevent broccoli head rot.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not repeat the application or rotate with other strobilurins. See label for list of allowed brassica crops.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; PHI 1d, REI 12h, Groups 11 & 3.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

boscalid (Endura): 6.0 to 9.0 oz/A; PHI 0d, REI 12h, Group 7.

botanical extract (Ecoswing^{OG}): 1.5 to 2.0 pt/A; PHI 0d, REI 4h.

chlorothalonil (Bravo Weather Stik): 1.5 pt/A; PHI 7d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.5 to 0.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Alette.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 7d, REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage.

fenamidone (Reason SC): 8.2 fl oz/A; PHI 2d, REI 12h, Group 11. Do not alternate with other Group 11 fungicides.

flutriafol (Rhyme 2.08 SC): 5 to 7 fl oz/A; PHI 0d, REI 12h, Group 3.

mancozeb (Manzate Pro Stick): 1.6 to 2.1 lb/A; PHI 7d, REI 24h, Group M3. Cabbage and broccoli only.

penthiopyrad (Fontelis): 14.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

potassium bicarbonate (MilStop): 2.5 to 5.0 lb/100 gal; PHI 0d, REI 4h, Group NC. See label for small volume application rates.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11.

triflumizole (Procure): 6 to 8 fl oz/A; PHI 1d, REI 12h, Group 3.

■ Black Leg (*Phoma lingam*)

Use 3- to 4-year crop rotation. Start with certified, disease-free seed. Remove and destroy infected seedlings in seedbeds. Improve soil drainage and air circulation. Eliminate brassica weeds. Avoid working in fields when they are wet. Promptly incorporate plant debris after harvest.

iprodione (Rovral 4F): 2.0 pt/A; PHI 0d, REI 24h, Group 2. Broccoli ONLY.

potassium bicarbonate (MilStop^{OG}): 2.5 to 5.0 lb/100 gal; PHI 0d, REI 4h, Group NC. See label for small volume application rates.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11.

thiram (Thiram 42-S): 8 lb/A. Seed treatment; REI 24h, Group M3.

■ Black Rot (*Xanthomonas campestris* pv. *campestris*)

Use a 4-year rotation of seed beds. Start with certified disease-free seed or treat seed with hot water. Eliminate cruciferous weeds and volunteers. Do not work in wet fields.

acibenzolar-S-methyl (Actigard): 0.5 to 1.0 oz/A; PHI 7d, REI 12h, Group P1.

copper hydroxide (Kocide 3000): 0.5 to 0.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; PHI 7d, REI 48h, Groups M3 & M1.

■ Club Root (*Plasmodiophora brassicae*)

Maintain soil at a pH of 6.8 or higher. Apply 1,500 lbs. of hydrated lime 6 weeks prior to planting to raise pH to 7.2 or more. At present, if club root is introduced into the soil, it can only be delayed, not defeated. A 4-year rotation is recommended for cole crops. If club root is detected, increase to a 7-year rotation. Then the PCNB and pH adjustment may reduce the viable club root spores to below economic threshold levels of infection for many growing seasons to come. Cold, wet soils favor club root and its spore survival. Resistant cultivars of some brassica crops are available. Prevent the movement of infested soil into uninfested fields.

cyazofamid (Ranman): 12.9 to 25.75 fl oz/100 gal; PHI 0d, REI 12h, Group 21. Tank mix with an organosilicone surfactant. Transplant soil drench or soil incorporation. See labels for details.

fluazinam (Omega 500 F): 6.45 fl oz/100gal, transplant drench at 3.4 fl oz solution per plant. 2.6 pts/A soil incorporation; REI 48h, Group 29.

PCNB (Blocker 4F): Rate varies depending upon application method - see label; REI 12h, Group 14.

■ Downy Mildew (*Hyaloperonospora parasitica*)

Improve air movement around plants by proper plant density and row orientation. Irrigate early in the day to speed drying of foliage. Plant resistant varieties. Treat seed with appropriate fungicides. Resistant cultivars of some brassica crops are available.

acibenzolar-S-methyl (Actigard): 0.5 to 1.0 oz/A; PHI 7d, REI 12h, Group P1.

ametoctradin plus dimethomorph (Zapro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 and 40.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.12 to 1.0 lb/A as a soil drench; PHI 0d, REI 4h, Group 44.

chlorothalonil (Bravo Weather Stik): 1.5 pt/A; PHI 7d, REI 12h, Group M5. Read label for replant restrictions.

copper hydroxide (Kocide 3000): 0.5 to 0.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyazofamid (Ranman): 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Tank mix with an organosilicone surfactant.

dimethomorph (Forum): 6.0 fl oz/A; PHI 7d, REI 12h, Group 40. Apply only in combination with a labeled rate of another non-group 40 fungicide. Do not make more than 2 sequential applications of Forum before alternating to a fungicide with a different mode of action.

fenamidone (Reason SC): 5.5 to 8.2 fl oz/A; PHI 2d, REI 12h, Group 11. Do not alternate with other Group 11 fungicides.

fluazinam (Omega 500F): 15.35 fl oz/A; PHI 7d, REI 48h, Group 29. Cabbage and Chinese cabbage only.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. Tank mix with a fungicide from a different group.

fosetyl aluminum (Aliette WDG): 3.0 to 5.0 lb/A; PHI 3d, REI 12h, Group 33. Do not mix with copper fungicides. Lower rates of Aliette (2 to 3 lb) can be used when tank mixed with another fungicide labeled for downy mildew control.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; PHI 7d, REI 48h, Groups M3 & M1. Broccoli and cabbage only.

mandipropamid (Revus): 8.0 fl oz/A; PHI 1d, REI 12h, Group 40. A spreading/penetrating type adjuvant must be added.

mefenoxam (Ridomil Gold SL): 0.125 to 0.25 pt/A; PHI 7d, REI 48h, Group 4. Do not apply foliar sprays of Ridomil Gold SL without a labeled tank mix partner.

mefenoxam plus chlorothalonil (Ridomil Gold/Bravo): 1.5 pt/A; *PHI 7d, REI 48h, Groups 4 & M5*. See label for plant-back restrictions and restrictions on certain crucifers.

oxathiapiprolin (Orondis Ultra A): 2.0 to 4.8 fl.oz/A; *PHI 0d, REI 4h, Group 49*. Begin foliar application prior to disease development. Use higher rate when disease is present.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that heat or moisture stressed. Do not apply directly to copper treated plants within 20-day interval to avoid plant injury.

potassium bicarbonate (MilStop^{OG}): 2.5 to 5.0 lb/100 gal; *PHI 0d, REI 4h, Group NC*. See label for small volume application rates.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; *PHI 0d, REI 12h, Group 11*.

Reynoutria sachalinensis extract (Regalia^{OG}): 0.5 to 4.0 qt/A ground application; or 0.5 to 1.5 qt/A foliar application; *PHI 0d, REI 4 h, Group P5*. Apply to ensure thorough coverage. See label for specific application instructions.

■ *Fusarium* Yellows

The pathogen is soil-borne and may also be seed-borne. Plant resistant varieties. Prevent the movement of infested soil to clean fields. Provide adequate fertility; potassium deficiency increases disease severity.

■ Seed Decay and Damping-off

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.12 to 1.0 lb/A as a soil drench; *PHI 0d, REI 4h, Group 44*.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/lb seed; *REI 48h, Group 4*. For Pythium damping-off protection.

***Streptomyces griseoviridis* strain K61 (Mycostop^{OG}):** 0.13 oz/lb seed.

thiram (Thiram 42-S): 8.0 lb/100 lb.; *REI 24h, Group M3*.

■ Wire Stem, Crater rot, and Head rot (*Rhizoctonia solani*)

Diseases caused by *R. solani* include wirestem and damping-off (seedlings), crater rot (rutabaga, turnip, and radish), and bottom or head rot (cabbage). *Rhizoctonia* can be carried on the seeds of most brassica species and a natural inhabitant of the soil where it survives indefinitely. Start with certified, disease-free seed and sterilized soil. Avoid soil previously used for brassica production. Practice good sanitation throughout crop cycle. Successful sanitation in transplant production prevents further need for fungicide drenches. Use treated seed for direct seeding into field. Practices that encourage rapid germination and establishment limit disease development. Avoid planting transplants too deeply. Rotate crops. Do not plant susceptible crucifers in fields with undecomposed crop residues. No highly resistant cultivars are available. Fungicide treatments in the field have limited effectiveness.

PCNB (Blocker 4F): Rate varies depending upon application method - see label; *REI 12h, Group 14*. Pathogen referred to as *Corticium solani* on label.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19*.

■ Turnip Mosaic Virus

Turnip mosaic virus can infect most brassica crops but it is most commonly seen in Chinese cabbage and bok choy. It is spread by aphids in a nonpersistent manner; therefore, insecticides are of little or no value in controlling its spread. This virus survives the winter in perennial weeds. It is spread by many species of aphids. Resistant cultivars include: Nabyeng, Kongng, Tip Top and Ta Feng. These cultivars may not be completely resistant and may have some intolerance to heat.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

A spreader-sticker should be used with insecticides on these crops as it will help provide better coverage and more insecticide persistence.

■ Cabbage Aphid (*Brevicoryne brassicae*)

Only crops and weeds in the brassica family are suitable hosts for cabbage aphid (CA). Cabbage, cauliflower, broccoli and Brussels sprouts are most severely affected, but other crops may become infested. Aphids tend to be more of a problem in fall plantings. Adults, both winged and wingless, and nymphs are grayish green with a dark head and short, dark cornicles, but appear more grayish white because the body is covered with a fine, white, powdery secretion. In fall, eggs are laid on the underside of leaves of the same crops or weeds that were fed on during the summer, and survive the winter on brassica host plants. This differs from the life cycle of many aphid pests of vegetables, where eggs are laid and overwinter on alternate hosts outside the field. Eggs typically hatch in April. Nymphs feed and develop into reproductive females who produce live young without mating. Winged adults disperse with wind and infest new crops. There are multiple summer generations and potential for huge population growth, especially where long-season crops are infested early. CA prefers to feed on young leaves, flower buds or seed stalks in the upper part of the plant and also feeds in developing Brussels sprout buds. Dense colonies may develop. Feeding injury includes wrinkled and downward-curling leaves, yellow leaves, reduced growth, contamination with aphid honeydew, and contamination of the marketable parts of the plant with aphids. CA can also transmit cauliflower mosaic and cabbage ring spot virus, among other viruses; transmission is non-persistent, with virus particles passed to new plants by probing. Natural enemies can suppress cabbage aphid populations, but may

not be able to prevent high densities that may occur in cool fall weather. Cultural controls include soil incorporation of crop residues immediately after harvest or, for overwintering brassicas, before eggs hatch in spring. Control brassica weeds in or near fields. Check transplants to be sure they are clean. Use reflective mulch to repel aphids. Use selective products when controlling other pests to conserve beneficials. If CA is a consistent problem, systemic insecticides used at planting or sidedress may eliminate early infestations. Scout weekly to determine % infested plants, starting before harvested portions of the plant form. Treat if >10% of the plants are infested with aphids, especially after heads or sprouts begin to form. Or select 10 leaves at 10 sites for 100 leaves per field, and treat if >20% have aphids. Coverage of all leaf surfaces, buds and new growth is key. Waiting until there are heavy outbreaks or until just before harvest makes it hard to prevent loss of marketable yield.

Green peach aphid (*Myzus persicae*) can also infest brassicas. For more information, see green peach aphid in the Pepper section.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 14d, REI 24h, Bee: H, Group 1B. For green peach aphid. For Brussels sprouts and cauliflower only.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

afidopyropen (Versys): 1.5 fl oz/A; PHI 0d, REI 12 h, Bee: L, Group 9D.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

Beauveria bassiana (Mycotrol ESO): 8 to 32 oz/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M. Suppression only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

dimethoate (Dimethoate 4EC): 8 to 16 oz/A for broccoli and cauliflower, 8 oz/A for kale and mustard, 16 oz/A Brussels sprouts; PHI 7d broccoli and cauliflower, 14d kale and mustard, 0d Brussels sprouts, REI 48h, Bee: H, Group 1B. Broccoli, cauliflower, kale, mustard, Brussels sprouts only.

dinotefuran (Safari 20SG): 0.16 to 0.32 oz/1,000 sq ft; 3.5 to 7 oz/100 gal; 7 to 14 oz/A; REI 12h, Bee: H, Group 4. Broccoli, Brussels sprouts, cabbage, cauliflower and kohlrabi transplants only while in greenhouse. Not for field use.

dinotefuran (Venom): 1 to 4 oz/A for foliar applications or 5 to 7.5 oz/A for soil applications to head and stem Brassicas. 2 to 3 oz/A for foliar application only to leafy Brassicas; PHI 1d foliar, 2PHI 1d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. For head and stem Brassicas only.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay. Do not apply during bloom or if bees are actively foraging. For head and stem brassicas only; PHI 21d, REI 24, Bee: H, Group 3.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d, REI 12h, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 12 oz/A; PHI 1d, REI 4h, Bee: L, Group 4D.

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A soil; 1.3 oz/A foliar; PHI 21d soil, 7d foliar, REI 12h, Bee: H, Group 4A.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with companion labeled aphicide.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. For head and stem Brassicas only. Suppression only.

malathion (Malathion 57 EC): 1 to 2 pt/A for broccoli, Brussels sprouts, cauliflower, cabbage, kohlrabi; 1 to 1.6 pt/A for kale and mustard greens; 1.5 to 1.6 pt/A for collards; PHI 2d broccoli, Brussels sprouts, cauliflower; 7d cabbage, kale, collards, kohlrabi, mustard greens, REI 48h broccoli, Brussels sprouts, cabbage, cauliflower; 24h kohlrabi; 12h collards, kale, mustard greens, Bee: H, Group 1B.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfil): 2.75 oz/A; PHI 7d, REI 12h, Bee: L, Group 9A. Selective control of aphids including cabbage aphid. Translaminar.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 1d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; PHI 3d, REI 12h, Bee: H, Group 4C.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d leafy Brassica greens, 0d head and stem brassicas, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an

in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

tolfepnyrad (Torac): 17 to 21 fl oz/A; *PHI 1d, REI 12 h, Bee: H, Group 21A.*

■ **Cabbage Looper (*Trichoplusia ni*), Diamondback Moth (*Plutella xylostella*) and Imported Cabbageworm (*Pieris rapae*)**

Diamondback moth (DBM) and imported cabbageworm (ICW) are pests throughout the growing season, while cabbage looper (CL) generally does not become a pest until mid- to late-season.

Imported cabbageworm (ICW) is the offspring of the cabbage butterfly, a daytime flyer often visible in brassica fields. Wings are white, and the forewing has a dark border and 1 to 2 round black spots. Eggs, laid singly on leaves, are about 0.125" in length, light green or yellow, and slightly elongated, standing upright. Imported cabbageworm caterpillars are gray-green with a thin yellow line down the back, slightly fuzzy, reach 1.25" in length, and are sluggish when touched. Feeding and resting occur on the underside of leaves, and larvae feed more heavily in the center or head of cabbage or broccoli. Damage includes round or ragged feeding holes and deposits of wet, green or brownish frass. The overwintering stage is the chrysalis (pupa), which is green or brown, smooth, with 3 pointed ridges on its back. There are 3 to 4 generations per year with adults first appearing in May.

Cabbage looper (CL) does not overwinter in New England but arrives in migratory flights from farther south. Generally, numbers are not significant until late July or August. Adult moths are mottled gray-brown, 0.75" long, with a distinct, round, silver-white mark on the wing. Bucket-type pheromone traps can be used to monitor moth flight. Eggs are globe-shaped, light green or yellow, and laid underneath the foliage. Caterpillars are light green, with wavy, white or light yellow lines down the back and sides, reaching 1.5" to 2" when full grown. Cabbage loopers of any size will raise the middle of their body in a characteristic "loop" shape. Feeding damage from older larvae consists of ragged, large holes in foliage, on both frame leaves and heads.

Diamondback moth (DBM) adults are small (<0.5"), light brown with a yellow diamond-shaped marking, and rest with their wings folded together like a tent. Adult moths are active at dusk and during the night. Caterpillars reach 3/4" in length, are light green, and are segmented and pointed at both ends. When disturbed they wiggle vigorously and may drop off the plant on a string of silk. Feeding causes small, round holes and tends to be spread across the foliage rather than concentrated in the head.

Incorporate crop residues shortly after harvest to reduce movement to successive plantings and reduce overwintering populations. Populations are suppressed by a wide range of natural enemies. Parasitic wasps that attack caterpillars include *Cotesia rubecula* on ICW and *Diadegma insulare* on DBM; their small white cocoons may be found on leaves.

Scout fields by checking leaves (top and bottom) on 25 plants across the field. In the Northeast, there is generally no need to treat young plants unless weather conditions delay plant development and at least 35% of them are infested

with any of these pests. Treat plants between the start of heading and harvest if 20% or more of the plants are infested. The most critical time to scout and apply chemical controls is just prior to head formation. Use a 10% to 15% threshold throughout the season for kale, collards, mustard, and other leafy greens.

Do not use less than 50 gal spray material/A; higher volumes provide better coverage. Better coverage of lower leaf surfaces can be achieved by using drop nozzles. Use a spreader-sticker. Use selective materials to spare beneficials that help control aphids and caterpillars. DBM has become resistant to many synthetic and microbial insecticides. Even if you are getting excellent control of this pest with the materials presently being used, you should alternate between effective materials to retard development of resistance. Newer materials and the aizawai strain of *Bacillus thuringiensis* will usually provide better control of resistant DBM than older products. Use transplants grown in New England to avoid importing DBM that have already developed resistance to one or more classes of insecticides.

acephate (Orthene 97): 1 lb/A; *PHI 14d, REI 24h, Bee: H, Group 1B.* For Brussels sprouts and cauliflower only. DBM has developed resistance in some areas.

acetamiprid (Assail 30SG): 4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 4A.* For suppression of DBM only.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A DBM and ICW, 3.2 to 3.8 oz/A looper; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.*

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A.*

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. Particularly effective against DBM. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A DBM & ICW, 0.5 to 1 lb/A looper; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. Particularly effective against DBM. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

***Beauveria bassiana* (Mycotrol ESO):** 16 to 32 oz/A; *PHI 0d, REI 4h, Bee: L, Group 22.* Use high rate for CL. May be used alone or tank mixed with *Bacillus thuringiensis* products. Takes 7 to 10 days after application to see control.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.4 oz/A for CL and ICW, 2.4 to 3.2 oz/A for DBM; *PHI 0d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 10 to 20 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M, Group un.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 3d broccoli, Brussels sprouts, cabbage, cauliflower and kohlrabi, 14d Chinese cabbage, collards, kale and mustard greens, REI 12h, Bee: H, Group 1A. DBM and ICW only.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 3d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through chemigation and as a foliar spray. Do not apply more than twice to any generation of diamond back moth.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cryolite (Prokil Cryolite): 8 to 16 lb/A; PHI 7d, REI 12h, Bee: L, Group un.

cyantraniliprole (Exirel): 10 to 17 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A for loopers, 5 to 10 oz/A for DBM and ICW; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A for DBM and ICW, 3.2 to 4.8 for CL; PHI 7d head and stem, 14d leafy brassicas, REI 12h, Bee: H, Group 6. Rotate to another product after 2 applications.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A for most species, 2.9 to 5.8 oz/A for ICW on broccoli, cabbage, cauliflower, and Chinese cabbage; PHI 3d broccoli, cabbage, cauliflower, Chinese cabbage, kohlrabi, 7d collards and mustard greens, REI 12h, Bee: H, Group 3A. Use high rate for mustard greens. Not for DBM. On kohlrabi, not for ICW.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A. For CL and ICW on head and stem brassicas only. May be combined with DiPel DF to control ICW and CL on head and stem brassicas only - see label for rates; PHI 7d, REI 24, Bee: H, Group 3.

flubendiamide (Belt SC): 2.0 to 2.4 oz/A; PHI 1d, REI 12h, Bee: L, Group 28.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A for looper and ICW, 1.02 to 1.54 oz/A DBM; PHI 1d, REI 24h, Bee: H, Group 3A. Head and stem Brassicas only.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h, Bee: H, Group 22. Use high rate for DBM. Add a wetting agent to improve spray coverage.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A for CL and ICW, 1.28 to 1.92 oz/A for DBM; PHI 1d, REI 24h, Bee: H, Group 3A. For head and stem Brassicas.

malathion (Malathion 57 EC): 1 to 2 pt/A for broccoli, Brussels sprouts, cauliflower, cabbage, kohlrabi, 1 to 1.6

pt/A for kale and mustard greens; 1.6 pt/A for collards; PHI 2d broccoli, Brussels sprouts, cauliflower, 7d cabbage, kale, collards, kohlrabi, mustard greens, REI 48h broccoli, Brussels sprouts, cabbage, cauliflower; 24h kohlrabi; 12h collards, kale, mustard greens, Bee: H, Group 1B. Not for DBM except on collards.

methomyl (Lannate* LV): 1.5 to 3 pt/A for CL and DBM, 0.75 to 3 pt/A for ICW on broccoli, cabbage, cauliflower, 1.5 to 3 pt/A for ICW on Brussels sprouts, collards, kale, mustard greens; PHI 1d cabbage, 3d broccoli, Brussels sprouts, cauliflower, 10d Chinese cabbage, collards, kale, mustard greens, REI 48h, Bee: H, Group 1A. Not for ICW or DBM on Chinese cabbage.

novaluron (Rimon 0.83EC): 6 to 12 oz/A; PHI 7d, REI 12h, Bee: L, Group 16B. Not labeled for collards, kale.

permethrin (Pounce* 25WP): 3.2 to 6.4 oz/A for Brussels sprouts, cauliflower, cavalo broccolo and kohlrabi, 3.2 to 12.8 oz/A for broccoli, Chinese broccoli, cabbage and Chinese cabbage; PHI 1d, REI 12h, Bee: H, Group 3A. Not for other Brassica crops.

methoxyfenozide (Intrepid 2F): 4 to 8 oz/A for ICW and CL; 12 to 16 oz/A for DBM; PHI 1d, REI 4h, Bee: L, Group 18. Suppression only for DBM.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Efficacy improves with the addition of an adjuvant.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A looper & ICW, 1.5 to 4 oz/A DBM; PHI 1d, REI 4h, Bee: M, Group 5. See label for resistance management restrictions for DBM.

tebufenozide (Confirm 2F): 6 to 8 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Use low rate for early season applications to young, small plants. Use of an adjuvant is recommended. Not for DBM.

tolfenpyrad (Torac): 17 to 21 fl oz/A; PHI 1 d, REI 12 h, Bee: H, Group 21A.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A for DBM, ICW, 3.4 to 4.3 for CL; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cabbage Maggot (*Delia radicum*)

Cabbage root maggot is a pest of all types of brassicas, but is particularly damaging in cabbage, broccoli, Chinese cabbage, radish, turnips, and rutabaga. The first flight in April and May damages early spring brassicas, and the third flight from mid-August into September primarily injures fall root crops. Flies overwinter as pupae near roots of fall brassica crops and weeds. Adult flies become active at about 288 growing degrees days (GDD, base temperature 40°F), which occurs 1 to 2 weeks after forsythia starts to bloom and when yellow rocket (winter cress, *Barbarea vulgaris*) blooms. Fifty percent emergence (peak flight) occurs at about 450 GDD (base 40°F). Adult flies are delicate,

hump-backed, gray-brown flies with long legs, about 5 to 7 mm long. Small (1.1mm), white, bullet-shaped eggs are laid singly or in clumps in the top 1-3 inches of soil, near the stem. Wet areas with heavy or rich soil are attractive for egg-laying. Maggots are white with black mouth hooks, feed on roots, and grow to 8 mm. The oval, brown pupae are found close to the roots. There are 2 to 3 generations per year in New England. Root damage causes plants to wilt, turn yellow or purple, become stunted or delayed, or die. Early infestation and large pest populations increase plant losses. Eggs are killed by exposure to soil temperatures above 95°F for several days in a row, especially in dry soil. Often these conditions occur in late May or early June.

Incorporate and disk brassica crop residues after harvest to expose and kill pupae, especially in the fall. Rotate spring crops to fields that were not planted with brassicas the previous fall. Avoid spring applications of manure or compost, which increase attractiveness of the field for egg-laying. Avoid wet fields or sections of the field. Protect spring crops with spunbonded row covers, and use covers only on rotated fields, or else the flies will emerge under the covers. Place covers over the crop at the time of seeding or transplanting and seal the edges with soil. Time your seeding or transplanting to avoid exposing young plants to peak flight periods; delay spring crops until after peak flight and when soils warm up.

Most labeled materials are labeled only for use pre-plant, at the time of planting or seeding—either in the seed furrow or as a transplant drench—or immediately after setting transplants. Use pre- or at-plant treatments only if damaging populations are expected, such as in fields with high organic matter or a history of infestations. Scout transplant trays before setting out plants in the field. Treat transplants if eggs are found, either in the tray, in transplant water, or as a post-plant drench, as labels allow. A pencil is a good tool to gently stir the soil at the base of the plant and look for eggs. Yellow sticky cards placed near brassicas capture adult flies, and along with GDD, are a good indicator of the onset of adult flight. Scout for eggs—in transplant trays and the field—as soon as flies are active. In the field, finding an average of 1 egg per plant can indicate a damaging population. Again, control options are limited once plants are in the field, but scouting to understand infestation levels can help inform management decisions in future plantings. Resistance to organophosphate (group 1B) insecticides has been documented; rotate among chemical classes where possible to retard development of resistance.

bifenthrin (Capture LFR): 3.4 to 6.8 oz/A; REI 12h, Bee: H, Group 3. Apply as a 5 to 7-inch T-band over the open seed furrow, or in-furrow with the seed.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 3d, REI 4h, Bee: L, Group 28. May only be applied as transplant water treatment to soil at planting. For suppression only.

chlorpyrifos (Lorsban 4E): Pre-plant: 4.5 pint/A (4 pint/A for cauliflower); At- or post-plant: 1.6 to 2.75 oz/1000 row ft (1.6 to 2.4 oz/1000 row ft for cauliflower); PHI 30d, REI 24h, Bee: H, Group 1B. Apply pre-plant as a broadcast spray and incorporate same day into top 2" to 4" of soil, or apply to direct seeded crops as a 4" band over the row at planting time. May also be applied to transplanted crops as

spray directed to base of plants immediately after setting. Do not add adjuvants or apply as a foliar spray.

cyantraniliprole (Verimark): 10 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

diazinon (Diazinon* AG500): Pre-plant incorporation applications: 2 to 3 qt/A; transplant water drench applications: 4 to 8 oz/50 gal water; PHI 7d, REI 4 days, Bee: H, Group 1B. Broccoli, Brussels sprouts, cabbage, cauliflower only. Transplant water treatments may result in stand reduction due to plant stress at time of transplanting.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. For direct seeded crops, apply directly to base of plants and adjacent soil when crop has developed to the two true leaf stage, and make second application 2-3 weeks later. For transplanted crops, apply immediately after transplanting and make second application 2-3 weeks later. A third application may be needed under high cabbage root maggot pest pressure conditions, such as when there is a large amount of debris from a previous brassica crop or when adjacent brassica fields are being harvested. For optimum control, direct the spray in a narrow band at the base of the plants. Do not make more than three applications of Group 5 insecticides (spinetoram and spinosad) per crop cycle for cabbage root maggot suppression. For brassica leafy vegetables only (e.g., broccoli, Brussels sprouts, cabbage, kale). Not for brassica roots (e.g., radish, turnip).

spinosad (Entrust SC^{OG}): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. For direct seeded crops, apply directly to base of plants and adjacent soil when crop has developed to the two true leaf stage, and make second application 2-3 weeks later. For transplanted crops, apply immediately after transplanting and make second application 2-3 weeks later. A third application may be needed under high cabbage root maggot pest pressure conditions, such as when there is a large amount of debris from a previous brassica crop or when adjacent brassica fields are being harvested. For optimum control, direct the spray in a narrow band at the base of the plants. Do not make more than three applications of Group 5 insecticides (spinetoram and spinosad) per crop cycle for cabbage root maggot suppression. For brassica leafy vegetables only (e.g., broccoli, Brussels sprouts, cabbage, kale). Not for brassica roots (e.g., radish, turnip).

tolfenpyrad (Torac): 21 fl oz/A; PHI 1d, REI 12h, Bee: H, Group 21A.

■ Cabbage Whitefly (*Aleyrodes proletella*)

An emerging pest in the Northeast United States, cabbage whitefly originates from Europe and is a pest in many areas of the world. Adults are small (1.5 mm) with white wings, and can be distinguished from greenhouse and sweet potato whitefly by two gray blotches on each forewing. Eggs are laid in a half-moon or circular pattern on the undersides of leaves. Immature stages are flat and scale-like. Both adults and nymphs feed on plant sap. Large populations will reduce plant vigor and quality, and adults and nymphs deposit honeydew on leaf surfaces on which sooty mold grows. Cabbage whitefly feeds and reproduces on brassicas, as well as other crops and weeds such as alfalfa, fava bean and dandelion. Preferred hosts are kale and Brussels sprouts.

beta-cyfluthrin (Baythroid* XL): 3.2 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. For suppression of adults only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetiva): 14 to 20 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection. Allow 1-3 days for material to be translocated into aerial portions of the plant. When populations are high, use a foliar control during this period.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil for heading brassicas, 2 to 3 oz/acre leafy; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 10 2/3 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging. Head and stem brassicas only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A soil, 1.3 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with a companion labeled insecticide.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only. Head and stem brassicas only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9A. Suppression only. Apply when whiteflies first appear.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Knack): 8 to 10 fl oz/A; PHI 7d, REI 12 h, Bee: L, Group 7C. Insect growth regulator, only effective on immature stages.

thiamethoxam (Actara): 3.0 to 5.5 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used in an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 23. Most effective on immature stages.

■ Cross-striped Cabbageworm (*Evergestis rimosalis*)

Formerly restricted to areas south of New England, this insect is now a significant pest of brassicas in CT, RI and MA. It has 2 to 3 generations per year and is most abundant on late-season plantings. Unlike the other major caterpillar pests on brassicas, the cross-striped cabbageworm (CSC) lays its eggs in batches (3 to 25) rather than singly, so caterpillars emerge in clusters. Egg batches are yellow, flattened, overlapping like fish scales, and attached to the lower leaf surfaces. Larvae grow to 3/4" long in 2 to 3 weeks. The caterpillars are light bluish-grey on top and green underneath, with numerous black bands across their backs and a yellow stripe down each side. Pupation takes place in soil, near the surface. Caterpillars produce small holes in leaves until only veins remain, or target terminal buds and sprouts, or may burrow into heads. Plants with larvae present are often completely skeletonized, while adjacent plants may be left undamaged. Plow under debris after harvest and control wild mustard and Shepherd's purse to help reduce pest populations. Scout weekly for caterpillars and damage. Spray if 5% of the plants are infested with CSC. Use selective insecticides to preserve parasitic wasps.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

buprofezin & flubendiamide (Vetiva): 10 to 20 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 3d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through chemigation and as a foliar spray.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4 h, Bee: H, Group 28.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M, Group un.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A; PHI 7d heading and stem, 14d leafy brassicas and turnip greens,

Crops

REI 12h, Bee: H, Group 6. Rotate to another product after 2 applications.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 0.25 to 2 lb/A DiPel DF; *PHI 7d, REI 24, Bee: H, Group 3.* For head and stem brassicas only.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; *PHI 3d, REI 12h, Bee: H, Group 22.* Add a wetting agent to improve spray coverage.

methoxyfenozide (Intrepid 2F): 8 to 10 oz/A; *PHI 1d, REI 4h, Bee: L, Group 18.*

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

tebufenozide (Confirm 2F): 6 to 8 oz/A; *PHI 7d, REI 4h, Bee: L, Group 18.* Use low rate for early season applications to young, small plants. Use of an adjuvant is recommended.

■ Cutworm

See cutworms in the Pepper and Outdoor Tomato sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

buprofezin & flubendiamide (Vetica): 10 to 20 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

carbaryl (10% Sevin Granules): 20 lb/A; *PHI 3d broccoli, Brussels sprouts, cabbage, cauliflower and kohlrabi, 14d Chinese cabbage, collards, kale, mustard greens, REI 12h, Bee: H, Group 1A.* For broadcast treatment only. Use within 30 days of crop emergence or transplanting.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M, Group un.*

cryolite (Prokil Cryolite): 8 to 16 lb/A; *PHI 7d, REI 12h, Bee: L, Group un.*

diazinon (Diazinon* AG500): 2 to 4 qt/A broadcast and incorporate before planting; *REI 24h, Bee: H, Group 1B.* For broccoli, Brussels sprouts, cabbage, collards, kale, mustard greens and cauliflower.

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esfenvalerate (Asana*XL): 5.8 to 9.6 oz/A; *PHI 3d, PHI 7d collards, REI 12h, Bee: H, Group 3A.* For broccoli, cabbage, cauliflower, Chinese cabbage, collards only.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC; *PHI 7d, REI 24, Bee: H, Group 3.* For head and stem brassicas only.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.* Head and stem Brassicas only.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.* For head and stem Brassicas only.

methomyl (Lannate* LV): 1.5 pt/A; *PHI 1d cabbage, 3d Brussels sprouts and cauliflower, 10d collards, REI 48h, Bee: H, Group 1A.* For variegated cutworm only.

methoxyfenozide (Intrepid 2F): 4 to 8 oz/A; *PHI 1d, REI 4h, Bee: L, Group 18.* Suppression only.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Cabbage and Chinese cabbage only.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft; *PHI 1d, REI 4h, Bee: M, Group 5.* Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Flea Beetles (*Phyllotreta cruciferae* and *P. striolata*)

In New England, two species are found on brassicas: the crucifer flea beetle (*Phyllotreta cruciferae*), which is uniformly black and shiny, about 2 mm in length; and the striped flea beetle (*P. striolata*), which is black with 2 yellow stripes on its back. These two species feed only on brassicas, and attack all types of brassica crops and weeds. Populations have increased over the past twenty-five years, so that on many farms flea beetle is a key pest of brassicas. Adult beetles overwinter outside cropped fields, in the soil surface and decaying plant residue of shrubby or woody borders. They search out host crops from early May into June and feed on leaves and stems, leaving small round pits and holes. Beetles hop quickly off the plant when disturbed. Eggs are laid in soil near the plant. Tiny white larvae feed on root hairs and pupate underground. New adults emerge from mid-July through early August and feed throughout August. Spring crops are damaged by over-wintered adults, while fall crops are damaged by summer adults, but it may be difficult to distinguish the generations when pressure is severe. Feeding generally declines in September, as adults leave fields for overwintering. There may be a small second generation of adults, which emerges in late September. Heavy feeding can kill seedlings, and moderate damage can stunt growth, delay maturity, reduce yield, and make crops unmarketable. Crops with more waxy leaves (*Brassica oleracea* such as cabbage, broccoli, and kale) are less attractive and feeding is more restricted to leaf margins, especially as crop matures. Crops with glossy leaves (e.g. *B. rapa* such as bok choy, Napa cabbage, or *B. juncea* such as mustard) are highly attractive; the whole leaf is damaged and the crop is susceptible until harvest.

Escape peak adult activity and avoid the buildup of high populations by rotating spring crops as far as possible from

last season's fall brassica crops, and planting late-season crops far from early brassicas. Where feasible, avoiding all early brassicas (until July) can be used to break the reproductive cycle. Incorporate and till crops immediately after harvest to expose and kill larvae and pupae. Provide adequate water and nutrients for crop growth. Avoid soil compaction. Floating row covers provide excellent protection of the crop if well secured with soil or bags around all edges immediately after seeding or transplanting. Remove and replace the same day for cultivation, as needed. Use attractive brassica types (*B. rapa* or *B. juncea*) on borders or within the field as a trap crop to draw beetles from less attractive types. Spray the trap crop to suppress beetles in the whole field, and to protect the trap crop for harvest. Scout across the field by counting beetles from above, then under the leaves, and estimating % leaf damage. Because brassica crops differ greatly in susceptibility and attractiveness there is no fixed economic threshold that applies to all crops and crop stages. A working threshold of 1 beetle per plant or >10% average leaf damage on 50% of the plants has proved effective in leafy greens and early stages of heading brassicas. Repeated applications may be needed if pressure is high.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

beta-cyfluthrin (Baythroid* XL): 2.4 to 3.2 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 3d cabbage, cauliflower, broccoli, Brussel sprouts, kohlrabi, 14d kale, collards, Chinese cabbage, mustard, REI 12h, Bee: H, Group 1A.

cryolite (Prokil Cryolite): 8 to 16 lb/A; PHI 7d, REI 12h, Bee: L, Group un.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

cyclaniliprole (Harvanta): 16.4 fl oz/A; PHI 1d, REI 4 h, Bee: H, Group 28.

dinotefuran (Venom): 1 to 4 oz/A for foliar application to head and stem brassicas, 2 to 3 oz/A for foliar application to leafy brassicas; PHI 1d, REI 12h, Bee: H, Group 4A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, 7d collards, REI 12h, Bee: H, Group 3A. For broccoli, cabbage, cauliflower, Chinese cabbage, collards only.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3 to 4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. For head and stem brassicas only. Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Head and stem brassicas only.

imidacloprid (Admire Pro): 1.3 oz/A; PHI 7d foliar, REI 12h, Bee: H, Group 4A. Foliar applications only.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. White residue is difficult to wash off leaves and heads; use only on very young leaves or leaves that will not be harvested.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. For head and stem brassicas.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Cabbage and Chinese cabbage only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinosad (Entrust SC^{OG}): 4 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Suppression only.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d leafy brassica greens, PHI 0d head and stem brassicas, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

tolfenpyrad (Torac): 17 to 21 fl oz/A; PHI 1d, REI 12h, Bee: H, Group 21A.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Onion Thrips (*Thrips tabaci*)

Onion thrips can be a significant problem on cabbage, where thrips feed on inner leaves of the head which are difficult to target by spraying. Damage may also occur on leafy brassicas such as broccoli, kale and collard, especially fall crops that are planted near a maturing onion crop. Thrips cause rough, golden or brown scars to form on the underside of open leaves, or produce scars and discolored layers within cabbage heads. Inspection with a 10X lens shows wounds to the epidermis from the rasping mouthparts, and scars from wounds that healed over. Thrips damage can be confused with oedema, a physiological disorder. See onion thrips in the Onion section for more information on identification, life cycle and management. Damage is most severe in hot, dry weather.

Tolerant varieties are the most cost-effective means of controlling thrips in cabbage. Varietal resistance is generally not available in other brassicas. Cabbage varieties that have showed tolerance in trials include Bobcat (highly tolerant), Benelli, Cairo, Superkraut 86, Bravo, Brutus, Cheers, Huron, and the various Vantage varieties. Varieties that are rated as susceptible include Atlantis, Bajonet, Charmant, Checkmate,

Crops

Market Prize, and Rinda. There are a great number of varieties, and not all have been tested. Also, available varieties change. Some seed catalogues rate thrips tolerance. Consult your seed suppliers and search recent research trials regarding thrips tolerance on new varieties.

Avoid thrips by not planting cabbage or fall brassica crops near alliums (onion family), or field crops such as alfalfa, clover, wheat, or oat that can harbor large populations of thrips, which may migrate to brassicas when these crops are cut or harvested. Scout young plants for presence and feeding injury. Begin applications when damage is first noticed; in cabbage, apply foliar treatments before heads form. In fall brassicas, the need for thrips controls may coincide with sprays for flea beetle or caterpillars and some insecticides control both. Repeat applications at 7- to 10-day intervals based on scouting. Use a shorter interval in hot, dry weather. Use spreader-sticker for better coverage. Apply in early evening, using high pressure and 100 gal water/A for best results. Systemic insecticides applied as a side dress up to 4-6 weeks after transplanting may provide adequate control in long-season cabbage. Rotate between insecticide groups to help prevent or delay resistance.

acetamiprid (Assail 30SG): 4 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A. Applications during the “cupping” stage of cabbage may be especially helpful in preventing injury.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

Beauveria bassiana (Mycotrol ESO): 8 to 32 oz/A; PHI 0d, REI 4h, Bee: L, Group 22. Thoroughly cover foliage. Takes 7 to 10 days after application to see control.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Suppression only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Suppression only.

dinotefuran (Safari 20SG): 0.16 to 0.32 dry oz/1,000 sq ft or 7 to 14 oz/A; REI 12h, Bee: H, Group 4A. Broccoli, Brussels sprouts, cabbage, cauliflower and kohlrabi transplants only while in greenhouse. Not for field use. Suppression only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Suppression only. Head and stem Brassicas only.

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A; PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil applications only.

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insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with companion labeled insecticide.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. For head and stem Brassicas. Suppression only.

novaluron (Rimon 0.83EC): 12 oz/A; PHI 7d, REI 12h, Bee: L, Group 16B. For head and stem brassicas.

permethrin (Pounce* 25WP): 3.2 to 6.4 oz/A for Brussels sprouts, cauliflower, cavalo broccolo, kohlrabi; 3.2 to 12.8 oz/A for broccoli, Chinese broccoli; PHI 1d, REI 12h, Bee: H, Group 3A. Not for other brassicas.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 6 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Efficacy improves with the addition of an adjuvant.

spinosad (Entrust SC^{OG}): 4 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Efficacy improves with the addition of an adjuvant.

sulfoxaflor (Closer SC): 5.75 oz/A; PHI 3d, REI 12h, Bee: H, Group 4C. Suppression only.

thiamethoxam (Actara): 3 to 5.5 oz/A; PHI 7d leafy brassica greens, 0d head and stem brassicas, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Slugs

There are several species of slugs that damage vegetable crops in New England, including grey garden, banded, marsh and spotted garden slugs. They may be dark gray, black, yellow or brown, covered with spots, and range from ¾ to nearly 4" long. Eggs may be laid several times per year, and slugs reach maturity in 3 to 6 months. They can become abundant in low- and no-till situations, in land that was recently fallow, along hedgerows, or wherever plant debris, mulches, stones or boards provide cover and daytime hiding places. Slugs usually feed at night but may also feed during the day during prolonged periods of cloudy wet weather. They are attracted to succulent leaves in moist environments, such as cabbage, pak choi, and Chinese cabbage. They will also feed on fruiting crops such as tomato, pepper and eggplant. Damage appears as shredded foliage or shallow fruit holes. They have a rasp-like tongue that wears a hole through the leaf instead of making a clean cut like a caterpillar or beetle. On some thick-leaved brassicas such as

cabbage, the hole will appear larger on 1 leaf surface and taper to a smaller hole in the opposite surface. Scout by looking for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours, or scout plants after dusk. Slug populations can also be monitored with unbaited traps consisting of 6"-deep holes covered with foil-covered shingles, which provide a cool hiding place during the day. To control slugs use habitat and cultural management supplemented by handpicking or trapping (on a small scale), repellents and toxic baits. Grow plants away from moist, shaded habitats, use clean cultivation, control weeds, and eliminate hiding places. Use trickle irrigation instead of overhead to reduce humidity and moist surfaces. On a small scale, handpick slugs after dusk using gloves and drop slugs in soapy water; repeat for several days. Baits should be applied to the ground near infested plants. It may be necessary to reapply after a rain, or make multiple applications when populations are high.

iron phosphate (Sluggo: Snail and Slug Bait^{OG}): 20 to 44 lb/A; *PHI 0d, REI 0h, Bee: L, Group 9B*. Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; *REI 12h, Bee: L*. Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

■ Swede Midge (*Contarinia nasturtii*)

A serious pest of crucifers in Europe. Recently introduced into North America, currently established in Quebec. In New England, it is established in northwestern Vermont, with range expanding southward and eastward. Adults are tiny (1/16"), weak-flying, brown flies, while larvae are translucent maggots when small and turn yellow as they grow to 1/8". They spend the winter as pupae in the top 2" of soil. Maggots infest the tissue near the growing tip and produce malformed plants with brown corky tissue, galls, no-heads, multi-heads, and twisted leaf petioles. Damage is most severe on broccoli, Chinese broccoli, Brussels sprouts, cauliflower and Asian greens. There may be 3 to 4 generations each year. Scout young plants near field borders and tree lines prior to heading or at the pre-cupping stage. Avoid importing infested plants by using New England-grown transplants. Use a 3-year crop rotation. Plant spring brassicas at least 1/2 mile from fall brassica fields. Deep plowing destroys pupae. Spring plantings may avoid peak populations later in the season. If possible, plant away from tree lines that shelter weak-flying adults. Report and confirm infestations to state IPM specialist or to the diagnostic lab.

acetamiprid (Assail 30SG): 4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 4*.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A*.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M. Suppression only*.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23*. Must be tank-mixed with a spray adjuvant

with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

glyphosate (Roundup Power Max): *REI 12h, Group 9*.

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22*. Broccoli, cabbage, and cauliflower only. Use 2-4 pts/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17*. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): *REI 12h, Group 8*. Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours of application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

clomazone (Command 3ME): *PHI 45d, REI 12h, Group 13*. Cabbage only. For seeded cabbage, apply 0.67 pt/A after seeding to the soil surface. For transplant cabbage, apply 0.67 to 1.3 pt/A to the soil surface prior to transplanting. Use the lower rate on coarse-textured soil and the higher rate on fine-textured soil. Will control annual grasses and many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for rotation restrictions.

DCPA (Dacthal 75WP): *REI 12h, Group 3*. Apply 6 to 14 lb/A at seeding or transplanting. Can be sprayed over transplants without injury. Apply at seeding only to leafy brassica greens (kale, mustards, turnips, etc.). Will not control ragweed, galinsoga or smartweed. Use lower rates on sandy soils.

napropamide (Devrinol 2-XT): *REI 12h, Group 15*. Apply up to 2 qt/A to a weed-free surface. A higher rate is permitted for use on broccoli in Maine only. See label for details. May be applied to direct seeded and transplanted crop as preplant incorporated or as a surface spray after planting. Must be shallow incorporate or incorporated thoroughly with irrigation if adequate rainfall does not occur within 24 hours of application (sufficient water to wet soil to a depth of 2" to 4").

oxyfluorfen (Goal): *REI 24h, Group 14.* Pre-transplant application only to broccoli, cabbage, and cauliflower. Apply 1 to 2 pt/A after completion of soil preparation but prior to transplanting. Do not incorporate. May cause temporary crop injury, and can cause severe crop injury if not applied properly. Read product label carefully before applying.

pendimethalin (Prowl H₂O): *PHI 60d for broccoli, PHI 70d for all others, REI 24h, Group 3.* Use as a postemergence-directed spray on the soil beneath plants and between vegetative rows of brassica head and stem vegetables. Apply a single application of up to 2.1 pt/A. For transplants, apply when crop is at the 2 to 4-leaf stage 1 to 3 days after transplanting. For direct-seeded crops, apply when crop is at the 2 to 4-leaf stage. Apply DO NOT spray foliage or stems because crop injury will occur. If rainfall or irrigation does not occur, mechanically incorporate to activate the herbicide. Apply before weed germination. Emerged weeds will not be controlled.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.* MASSACHUSETTS AND NEW HAMPSHIRE: Broccoli, cabbage, and leafy brassica greens only. MAINE: cabbage only. This is a restricted label available only to growers who register through the website www.farmassist.com and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Incorporate 1 to 1.5 pt/A before seeding crops, or 1 to 2 pt/A before transplanting (broccoli, brussels sprouts, cabbage, and cauliflower). Can be used before seeding only for greens (collard, kale, mustard and turnip). Select rate based on soil texture, see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Little or no control of ragweed, galinsoga, mustard or nutsedge.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 30d, PHI 14d for leafy brassica greens, REI 24h, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a

spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

clopyralid (Stinger): *PHI 30d, REI 12h, Group 4.* Apply 1/4 to 1/2 pt/A for postemergence control of common ragweed, galinsoga, prickly lettuce, sweet clover, and wild buckwheat and suppression of sowthistle. Stinger is very effective on small seedling annual and emerging perennial weeds less than 2" to 4" tall, but is less effective and takes longer to work when weeds are larger. Spray additives are not needed or required by the label and are not recommended. Stinger is a postemergence herbicide with some soil residual activity. See label for crop rotation restrictions, or injury may occur from herbicide carryover. Make 1 to 2 applications a year, but do not exceed 1/2 pt/A per year.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): *PHI 30d, PHI 14d for leafy brassica greens, REI 12h, Group 1.* Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PHYSIOLOGICAL DISORDERS

■ Oedema of Cabbage

Oedema is a physiological response of the plant to excessive soil moisture during periods of cool nights and warm, humid days. Many small scabby lesions form on the underside of the cabbage leaves. Avoid irrigation during times when day-night temperature variations are great. Oedema may be confused with thrips damage.

■ Head Rot and Brown Beading (Broccoli)

Both problems are caused by several factors. Problems with calcium uptake combined with rapid growth can result in either condition, even when soil calcium levels are high. Head rot results from bacteria breaking down the tissues under wet conditions, and brown beading results from individual flower buds aborting under dry conditions. Extended periods of wet or dry conditions during warm temperatures give rise to rapid plant growth while calcium uptake is diminished due to poor transpiration rates in the plants. Mixing varieties based on rate of maturity offers growers the only practical defense against either head rot or brown beading. Selecting a later-maturing cultivar to be

harvested along with your typical cultivar during those parts of the growing season when problems have typically occurred can reduce the risk of whole-crop losses during challenging weather conditions.

■ Cauliflower and Broccoli Premature Heading and Lack of Heads

Buttoning is most common when transplants are too old and past the juvenile growth stage when transplanted. Other stress factors such as low fertility, low moisture micronutrient deficiencies or disease and insects can also be causes. Strong healthy plants lacking heads can occur due to periods of extremely warm weather (days over 86°F and nights over 77°F).

■ Bracts (leaves) in Cauliflower or Broccoli Heads

High temperatures or low soil moisture can result in the formation of bracts, small leaves, between segments in the heads of cauliflower and broccoli.

■ Yellow or Brown Beads in Broccoli Heads

Yellowing of florets may be due to an over mature head, high storage temperatures after harvest, or exposure to ethylene. Brown beads in broccoli are areas where florets do not properly develop and die. Possible causes include nutritional imbalances, or feeding damage by insects such as harlequin bugs or tarnished plant bugs.

CARROT AND PARSNIP

Carrot (*Daucus carota*) and parsnip (*Pastinaca sativa*) both belong to the *Umbelliferae* (*Apiaceae*) family, along with several other crops including celery, fennel, dill, cilantro, and parsley. Best production of these root crops is obtained from deep, well-drained sandy loam soils. Raised beds tend to increase the depth of tilled soil and can help provide good root shape. Some growers chisel plow before forming beds to loosen the soil and enhance root development. Do not destroy soil structure by overworking soils or working them while wet. Some growers rototill to obtain a deep, friable soil. Hilling soil over the shoulders of the roots at the last cultivation can help reduce greening.

Types and Varieties

Carrot and Parsnip Varieties	
Roadside Market Carrot Bolero - nantes/imperator, A, C Mokum - nantes, A Ya Ya - nantes, A Napoli - nantes	Specialty Carrot Yellowstone - yellow White Satin - white Purple Haze - purple Rainbow - assorted colors Atlas - small round parisian type
Wholesale Market Carrot Maverick - imperator, A Sugar Snax 54 - imperator, A, C Sweet Baby Jane - nantes, C	Parsnip Harris Model Javelin Albion
Resistant or tolerant to: A: <i>Alternaria</i> , C: <i>Cercospora</i>	

Soil Fertility

Apply lime according to soil test recommendation to maintain soil pH at 6.5-6.8. Calcium levels should be maintained at a high level to avoid cavity spot. Calcium should be 60-85% base saturation.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15). Application of high amounts of nitrogen to parsnips can cause excessive top growth, increasing their susceptibility to diseases. Using urea as a source of nitrogen for sidedressing may increase the incidence of cavity spot. Fresh manure or urea as nitrogen source can result in branched roots. Manure may also create a food safety issue, so plan on at least 120 days between application of manure and harvest. If large amounts of potassium are needed or if soils are highly leachable, some of the potassium can be applied with the first nitrogen sidedressing application. Carrots and parsnips have relatively high requirements for potassium, but excessive applications can inhibit calcium uptake and thus increase the incidence of cavity spot.

Suggested rates of nitrogen, phosphorus and potassium are based on high yield expectations of 20-25 tons per acre for carrots. If soil type or other factors limit potential to a lower yield, reduce fertilizer application accordingly.

Planting

Carrots should be planted to a stand of 15 plants per foot of row, which requires 2-3 lb of seed/A (about 0.0625 oz per 100 feet of single row). Parsnips should be planted to a stand at 8-10 plants per foot of row, which requires 4-5 lb of seed/A (about 0.5 oz per 100 feet of single row). Parsnip seeds have a short life and lose viability quickly during storage; parsnip seeds should be purchased new each year.

Sow 0.5"-0.75" deep with row spacing 12"-18" with 3 or 4 rows per bed. Seeds should be scattered uniformly in a 3"-4" band when seeding with non-precision seeders. A more uniform stand may be obtained using pelleted seed and precision seeders to seed in bands of 3 rows, 1.5" apart.

These crops are slow to germinate; an adequate and constant moisture supply is necessary during this period. Parsnips require a long growing season (110-130 days) and should be seeded as early in the spring as practical.

Harvest and Storage

Carrots and parsnips must be topped before storage. Mature roots can be kept in good condition for 4-5 months at temperatures near 32°F if not allowed to freeze. Avoid relative humidity higher than 95%, which cause condensation and dripping. Carrots that are not fully mature can be stored only 4-6 weeks. Parsnips should not be harvested until fully mature for good quality. Parsnips can be left in the ground over winter but should be harvested before growth starts in the spring (this is risky because poor spring weather may prevent timely harvesting). Do not store these crops in a building with apples, pears or other ethylene producing fruits since bitterness can result.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Leaf Blight (*Cercospora*, *Septoria*, or *Alternaria*)**

Use certified, disease-free seed or treat seed with hot water or fungicides. Rotate fields. Irrigate early in the day to allow foliage to dry quickly. Use wider plant spacing and/or raised beds to improve air circulation. Plant resistant or tolerant varieties where available. Apply fungicides based upon a disease forecasting system.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 pt/A; PHI 0d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus propiconazole (Quilt): 14.0 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

boscalid (Endura): 4.5 oz/A; PHI 0d, REI 12h, Group 7. For *Alternaria* only.

chlorothalonil (Bravo Weather Stik): 1.5 to 2.0 pt/A; PHI 0d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

fluazinam (Omega 500F): 1.0 pt/A; PHI 7d, REI 48h, Group 29.

iprodione (Rovral 4F): 1.0 to 2.0 pt/A; PHI 0d, REI 24h, Group 2.

penthiopyrad (Fontelis): 16.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propiconazole (Tilt): 4 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin plus boscalid (Pristine): 8 to 10.5 oz/A; PHI 0d, REI 12h, Groups 11 & 7. Do not alternate with other Group 11 fungicides.

trifloxystrobin (Flint): 2.0 to 3.0 oz/A; PHI 7d, REI 12h, Group 11. Do not alternate with other Group 11 fungicides.

■ **Crater Rot (*Rhizoctonia carotae*)**

Crater rot caused by *Rhizoctonia carotae* is a post-harvest disease of carrot that results from prolonged cold storage

(greater than 30 days). The pathogen is soilborne and initial infection occurs before harvest. Late harvested carrots may have higher amounts of infection. The fungus then develops in cold storage (4 to 6°F), especially when there is a film of moisture or very high humidity. Under high disease pressure, carrots can be dipped in fungicides or inorganic salts prior to storage. Washing carrots in water can also reduce inoculum clinging to root surfaces. Disinfection of crates and other equipment minimizes disease development. Proper cold storage that avoids temperature fluctuations and condensation reduce disease and prevent dehydration. Removal of carrots from cold storage early can prevent losses.

■ **Parsnip Blight (*Pseudomonas marginalis*)**

Causes browning through the interior of the root. Practice at least a 2-year rotation.

■ **Root and Crown Rot (*Rhizoctonia*)**

A 2-year rotation is recommended to prevent buildup of disease-causing organisms. Avoid crops such as alfalfa and legume cover crops which can increase disease risk. Avoid cultivating late in the season. Maintain storage conditions at 50°F.

azoxystrobin (Quadris): See label for in-furrow and drench rates; PHI 0d, REI 4h, Group 11.

***Bacillus amyloliquefaciens* F727 (Stargus^{OG}):** 2 to 4 qt/A; PHI 0d, REI 4h, Group 44. Apply preventatively in a minimum of 50 gallons of water/A.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

***Trichoderma asperellum*, *T. gamsii* (Bio-tam^{OG}):** See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

■ **Sore Head (*Itersonilia perplexans*)**

Occurs on parsnip only. Plant on raised beds in well-drained soil. The variety Model is somewhat resistant. Rotate parsnip with non-susceptible hosts and control wild Apiaceae plant hosts. Start with certified, disease-free seed. Protect roots by covering crowns and exposed upper roots with soil. Deep plow plant residue to reduce soilborne inoculum. Rarely occurs on young plants. Monitor fields near maturity and harvest affected fields early. Fungicide sprays are not effective.

■ **Storage Rot (White Mold [*Sclerotinia sclerotiorum*] and Black Mold [*Thielaviopsis basicola*])**

Handle carrots carefully at harvest and washing. Use chlorine and change wash water frequently to reduce spread of pathogens. Clean and disinfect storage containers and harvesting

Plant Nutrient Recommendation According to Soil Test Results for Carrot and Parsnip

CARROT AND PARSNIP	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	50	150	100	50	0	300	200	75-100	0
Sidedress 4-6 weeks after planting	30-50	0	0	0	0	0	0	0	0
Sidedress when Roots are 1/2" in Diameter*	30-50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	110-150	150	100	50	0	300	200	75-100	0

* If expected yields will be less than 20 tons/A, the second sidedressing can be omitted.

equipment between batches. Cool carrots quickly to remove field heat. Inspect and dispose of infested carrots. Maintain storage and shipping temperatures of 32°F and 95% relative humidity.

pen thiopyrad (Fontelis): 16.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

thiabendazole (Mertect 340F): 41 fl oz/100 gal; REI 12h, Group 1.

fluazinam (Omega 500F): 1.0 pt/A; PHI 7d, REI 48h, Group 29.

■ *Xanthomonas* Leaf Blight (*Xanthomonas campestris* pv. *carotae*)

Xanthomonas leaf blight is easily confused with *Alternaria* leaf blight, and they can occur at the same time. “Waltham Hi-Color” and “Danvers” have some tolerance to *Xanthomonas*. Start with certified disease-free seed or treat seed with hot water. Rotate with non-susceptible crops on a 2- to 3-year cycle. Copper sprays partially reduce disease severity only if applied early in the crop cycle and repeated at 7- to 10-day intervals.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

■ Aster Yellows

Remove inoculum sources by controlling weeds (alternate hosts). Avoid fields near pastures or river banks that harbor susceptible vegetation. Destroy residues from susceptible crops immediately after harvest. Control the six-spotted leafhopper that carries the mycoplasma (see Carrot and Parsnip, Insect Control).

■ Root-Knot Nematode (*Meloidogyne*)

Low densities of root knot nematodes before planting means susceptible crops will suffer damage. Monitor soils for nematode populations. Rotate with non-hosts such as cereals. Practice soil solarization or field fumigation in the fall. See Soil Fumigation Outdoors, page 89.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aster Leafhopper (*Macrostelus quadrilineatis*)

Aster leafhopper is currently a minor pest in New England, but a major pest in the Midwest. Although it inflicts very little direct feeding injury to carrots or parsnips, it is important because it vectors aster yellows, a mycoplasma-like pathogen

which causes distortion and discoloration of leaves as well as stunted, hairy and bitter roots in both carrot and parsnip. Lettuce, celery, celeriac, parsley, corn and potato are also susceptible. Aster leafhoppers also feed in cereal grains, especially oats, wheat and barley, clover and various weeds. The adults are small, less than 4 mm, light green with grey wings, and have 6 pairs of black spots on the top and front of the head. Among vegetables, lettuce is the primary crop that is suitable for leafhopper reproduction. Eggs are laid in plant tissues, and the yellowish nymphs feed and develop into adults in 3 to 4 weeks. There are 3 generations per year in northern states. Aster leafhoppers migrate north annually from the southern US, and can arrive as early as May, sometimes already infected with the aster yellows pathogen. In northern states, they can also overwinter in the egg stage, on weeds or winter grains.

Unlike many insect-vectored viruses, transmission of the aster yellows mycoplasma is ‘persistent’. This means that to become infected with aster yellows, adults or nymphs must feed for at least 2 hours on an infected host, which could be a crop in a southern state prior to migration, or a local crop or weed. Weeds that may be infected include thistle, fleabane, wild lettuce, sow thistle, chicory, wild carrot, galinsoga, dandelion, plantain, and cinquefoil. There is an incubation period of 2 to 3 weeks inside the leafhopper; thereafter it is able to transmit the pathogen for the duration of its life. Transmission from the leafhopper to a non-infected plant also requires at least 2 hours of feeding. It takes 10 to 15 days for infected plants to show symptoms.

If aster yellows disease becomes a problem on your farm, plant tolerant or resistant varieties, which are available for carrot and lettuce. Control weed hosts and avoid growing susceptible crops in fields close to winter grains. Reflective or light-colored straw mulch effectively reduces aster yellows infection, and row cover prevents infection by keeping out leafhoppers. Cool, wet weather limits leafhopper activity and disease transmission. Monitor nearby grain fields or carrot crops in July and August using sweep nets. Thresholds widely used in the Midwest are based on the aster yellows index, which is the product of the percent infection of the leafhopper population (determined by testing) and the number of leafhoppers per 100 sweeps. At 2% infection, the threshold in carrots is 25 leafhoppers per 100 sweeps in susceptible varieties, and 37/100 in tolerant varieties. In the absence of actual test results for % infection, assume 2%. It is important to control leafhoppers before infection takes place. Because several hours of feeding are required for the aster leafhopper to transmit aster yellows to a plant, disease suppression can be achieved by killing the vector before inoculation occurs.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid*XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 7d, REI 12h, Bee: H, Group 1A.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Carrot only.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

imidacloprid (Admire Pro): 0.3 to 0.7 oz/1,000 row ft or 4.4 to 10.5 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{OC}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression and repellence only.

malathion (Malathion 57 EC): 2 pt/A; PHI 7d, REI 24h, Bee: H, Group 1B. Carrots only.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. Carrot only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

sulfoxaflor (Transform WG): 1.5 to 2.75 oz/A; PHI 7d, REI 24h, Bees: H, Group 4C.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 12 oz/A; REI 12h, Bee: H, Group 4A. Systemic insecticide used at seeding or within 24 h of seeding as an in-furrow or narrow surface band with sufficient water for incorporation, or in drip irrigation.

zeta-cypermethrin (Mustang*): 1.9 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Carrot Rust Fly (*Psila rosae*)

Carrot rust fly feeds on many umbelliferous crops and weeds. Though it is considered principally a pest of carrots, it can also damage parsnips, celery, celeriac, parsley and dill. Adults are slender flies, 4 to 5 mm long, with slightly iridescent wings, yellowish-brown head and legs, dark red eyes, and shiny black thorax and abdomen. Adult flies enter fields to oviposit and return to field edges on a daily basis. Clusters of 1 to 3 eggs are laid in the soil near the base of food plants. Larvae are milky-white to yellowish, without legs, tapered at the head with dark mouth hooks, and 6 to 9 mm when full grown. Root feeding of hatching larvae may kill young plants or cause forked, stunted or fibrous roots. Larvae burrow into the main root as they grow larger, then leave the root to form an oval brown pupa up to 10 cm deep in the soil. Sometimes larvae overwinter in fall carrot roots, but mainly pupa overwinter in the soil, and adults emerge in May and June. Cool, moist conditions favor adult emergence. Early season carrots are susceptible to attack by this first flight, especially the earliest successions, as flies tend to select larger carrots to lay eggs. The summer generation of adult flies emerges in August and is active through September, causing damage to late or long-season carrots. Fall damage may increase in later harvests. The larva mines the surface of the root, leaving trails and blotchy areas that develop a rusty color and render the root unmarketable. Wounds provide entry to plant pathogens. The foliage may become red or yellow. In carrot, the larval mines are mostly in the lower portion of the root, but in parsnip, they are in the upper portion. In celery, the larva may tunnel upward into the

crown and stalks. Damage is often worst near sheltered field edges, with damage decreasing toward the center of the field.

Avoid leaving crops in the field over the winter, where they support overwintering larvae or attract spring egg-laying. Because adults are weak flyers and are limited to one crop family, crop rotation to a separate field is effective. If possible, plant carrots in open fields where wind protects them from adult flights. The crop is most vulnerable around the edge of sheltered fields surrounded by woods. Row covers protect the crop from egg-laying. Intercropping with onion has been shown to reduce damage by carrot rust fly. Some varieties show partial resistance to rust fly. Stagger plantings to distribute risk, or if possible, time plantings to avoid the first and second flight periods. In the fall, harvest edges first, as these may have the most damage. Monitor flight with yellow sticky traps placed upright on a stake just above the canopy and several feet into the field; count flies twice weekly. Use multiple traps per field, especially along field edges that are sheltered from wind. Traps reflect population levels and indicate the beginning, peak and end of flight periods, and are used to time insecticides or determine when it is safe to remove row cover. In Quebec and Ontario, insecticides are recommended at thresholds of 0.1 to 0.2 flies per trap per day, although there are currently no available registered products in New England. Where active periods coincide, sprays for carrot weevil may help control carrot rust fly.

■ Carrot Weevil (*Listronotus oregonensis*)

Carrot weevil attacks crops and weeds in the *Umbelliferae* family, and can cause severe damage to parsley, dill, carrot, celery and parsnip. Adult beetles are brown, less than 6 mm long, with the typical weevil 'snout-like' mouthparts. They overwinter in soil or plant debris near previous host crops. Although able to fly, they travel and invade fields mostly by walking. In spring, females lay eggs into holes that they gouge in petioles or tops of roots, but only oviposit in plants that are older than 4 leaf stage. Egg-laying starts at 234 growing degree days (GDD), using a base temperature of 44.6°F. Young larvae tunnel in stalks or roots and may kill young plants. Larvae tunnel downward as they grow. Tunnels are very pronounced and may be invaded by fungi. Unlike carrot rust fly, feeding damage by weevil larvae is limited to the upper third of the root. Pupation takes place in the soil and new adults emerge from the soil after 1 to 2 weeks. There is generally 1 generation per year in New England. Weevils tend to be worse in organic soils. To prevent damage, rotate carrot and parsnip crops to new fields, to escape overwintering adults. Delay planting until after eggs have been deposited (90% of oviposition is expected to be completed by 820 GDD). Carrot-baited traps (Mason jar, Boivin or modified Boivin traps) deployed at field edges can be used to detect incoming adults. Sampling roots is an effective way to estimate the population of larvae. Insecticide must be applied before egg-laying begins, so timing is important; GDD can be a useful tool. Sprays targeting the adult beetles should be applied once or twice, 10 to 14 days apart, from the 1- to 3-leaf stage.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid*XL): 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana*XL): 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Begin treatment when weevils become active, and provide thorough spray coverage of crowns. For carrot only.

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OC}): 1 to 2 lb/A soil drench; PHI 0d, REI 4h, Bee: M, Group M.

malathion (Malathion 57 EC): 1 to 2 pt/A; PHI 7d, REI 24h, Bee: H, Group 1B. For parsnips only.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 14d, REI 48h, Bee: H, Group 1A. Use as a soil directed spray in 20 gal water/A. Must be incorporated into soil by water or mechanical means to a depth of at least 2". Carrot only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Cutworms

In carrots, cutworms feed on petioles, cutting them near the ground. One cutworm can destroy several plants in a single night. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms. Use spot treatments in affected areas.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OC}): 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

Bacillus thuringiensis kurstaki (Dipel DF^{OC}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 21d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 7d, REI 12h, Bee: H, Group 1A. Most effective on species that feed on upper portions of the plant.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. For carrot only.

methomyl (Lannate* LV): 0.75 to 1.5 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. For variegated cutworm on carrot only.

methoxyfenozide (Intrepid 2F): 8 to 16 oz/A; PHI 14d, REI 4h, Bee: L, Group 18. Suppression only.

spinosad (Seduce^{OC}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 1d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): restricted use. REI 12h, Group 22. Carrots only. Use 2-4 pts/A.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

linuron (Lorox DF): PHI 14d, REI 24h, Group 7. Parsnips only. Make a single application of 1.5 to 3 lbs/A after planting but prior to crop emergence. Seed should be planted at least 1/2 inch deep.

pendimethalin (Prowl H₂O): PHI 60d, REI 24h, Group 3. Carrots only. Apply 2pt/A to the soil surface within 2 days of seeding. Do not apply over the top of emerged carrots.

s-metolachlor (Dual Magnum): REI 12h, Group 15. MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. Carrots only. This is a restricted label available only to those growers who apply through the website www.farmassist.com and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

trifluralin (Treflan 4E): REI 12h, Group 3. Carrots only. Apply 1 to 2 pts/A as a preplant soil incorporated treatment. Select rate based on soil texture, see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Little or no control of ragweed, galinsoga, mustard or nutsedge.

■ Herbicides Used Pre- and Postemergence to Weeds

prometryn (Caparol 4L): PHI 30d, REI 12h, Group 5. Carrots only. Primarily controls annual broadleaf weeds. Annual grasses may only be suppressed. Can be applied preemergence and/or postemergence over the top to carrot. Up to three applications at the rate of 2-4 pt/A per application are permitted. Do not exceed 8 pt/A per crop cycle. Do not exceed one preemergence application (up to 4 pt/A) plus two postemergence applications each at up to 2 pt/A or one postemergence application at up to 4 pt/A. Use lower rate on coarse-textured sandy soils and the higher rate on fine-textured soils.

For preemergence use, follow with overhead irrigation if rainfall does not occur to activate.

For postemergence use, apply after the crop is at the six-leaf stage. Include nonionic surfactant (0.5% v:v, 2 qt per 100 gallons of spray) or crop oil concentrate (1% v:v, 1 gallon per 100 gallons of spray). Do not apply when temperatures exceed 85°F.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 30d, REI 24h, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluzifop (Fusilade DX): PHI 45d, REI 12h, Group 1. Carrots only. For grass weed control only. Apply 6 to 16 oz/A. See label to select rate based on grasses targeted for control. Allow for minimum 14-days between applications, and not to exceed 48 oz/A per year. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

linuraon (Lorox DF): PHI 14d, REI 24h, Group 7. Carrots only. Carrot varieties can vary in their tolerance to Lorox. Apply 1.5 to 3 lb/A after carrots are at least 3". Multiple applications are permitted, not to exceed a total of 4 lb/A per season. Apply before annual grasses exceed 2" tall and before broadleaf weeds exceed 6" tall. Do not exceed 40 psi spray nozzle pressure as crop injury may result. Do not apply when the temperature exceeds 85°F as crop injury may result. Do not apply Lorox as a tank mix with surfactant, nitrogen solution or other pesticides.

metribuzin (Metribuzin 75): PHI 60d, REI 12h, Group 5. Carrots only. Apply 0.3 lb/A when carrots have 5 to 6 true leaves and weeds are less than 1" tall and 1" in canopy diameter. A second application can be made 3 weeks after the first. Do not apply within 3 days of cool or wet weather or within 3 days of other sprays. Fair on grasses.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre;

complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Carrots only. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

CELERY AND CELERIAC

Celery (*Apium graveolens*) is a long-season crop that grows best under cool conditions (60°-75°F). A deep, loamy and fertile soil with an ample and uniform supply of water is ideal for celery. Muck soils are also used for celery production. Even though most of the celery root system is within the top 6" of soil, many roots penetrate as deep as 2'; thus, heavy clay soils are unsuitable. Hardpans should be avoided or disrupted before planting to allow for adequate drainage.

Celeriac (*Apium graveolens* var. *rapaceum*) is a smaller plant that looks like celery, but the edible portion is the swollen tuberous base, which has a strong celery-like flavor. The petioles or stalks are not edible. Celeriac is used in stews and soups, and is eaten fresh on salads. The plant is ready for harvest about 100-110 days from seed or 80-90 days from transplanting. Tubers may be blanched by covering with soil a few weeks prior to harvest. Cultural requirements are similar to celery.

Types and Varieties

Celery and Celeriac Varieties

Celery	Celeriac
Pascal strains	Brilliant
Utah 52-70	Diamant
Sabroso, A	
Tango	
Merengo, A	

Resistant or tolerant to: A = celery Anthracnose

Soil Fertility

Apply lime according to soil test to maintain soil pH at 6.0-6.8. Maintain a high level of calcium to avoid blackheart and sufficient boron to avoid brown petiole cracks ("brown check").

Celery and celeriac are heavy feeders and require adequate fertility to produce a quality crop. Use a liquid starter fertilizer at transplanting, especially with cool soil conditions. Use a high phosphorus starter fertilizer mixed at a rate of 3 lb/50 gals of water. Apply 8 fl oz (1 cup) per transplant.

Sidedress 50 lb N per acre 3-4 weeks after transplanting. On light soils, a second sidedressing may be necessary. The

second sidedressing application of nitrogen can be reduced or eliminated if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Celery is very susceptible to magnesium and calcium deficiencies. Magnesium requirements can be partially met by using dolomitic (high magnesium) limestone. Any further need of magnesium can be met by spraying the plants with Epsom salts (magnesium sulfate) at 8 lb/A per week until green color is restored. Inadequate uptake of calcium will cause a disorder known as blackheart, where the growing tips of the heart die and turn black. Provide a steady water supply to maintain even plant growth and calcium uptake and provide foliar applications of calcium nitrate or calcium chloride during prolonged dry periods. Maintain high calcium to potassium ratios to facilitate calcium uptake.

Boron, manganese and copper are also critical in the growth and development of celery. Plants grown on organic soils or mixes with low levels of boron and high levels of potassium often have brown, cross-checked cracks on the inside of the petiole. Add boron to fertilizer at planting and foliar apply it during dry periods. Utah 52-70 strains resist brown check. Tissue analysis is the best method of determining the sufficiency of these elements.

Planting

Celery should be seeded eight to ten weeks before transplanting into the field. Keep greenhouse temperatures above 55°F to prevent bolting and ensure continuous development. Do not lower temperature to harden plants. Transplant to the field in June when outside temperatures have warmed. Although this crop will withstand light frosts, bolting (premature flowering) will occur if temperatures below 40°F persist over a period of 10-14 days. Pelletized seed is generally used because of the small size of raw seed. Mature seed and ample moisture are critical for germination. Use two- or three-year old seed that has all matured and maintain planting media near field capacity. Priming seed improves germination. One ounce of seed produces about 15,000 plants. User 2-4 oz to produce enough plants for one acre (20,000-58,000 plants). Space rows 18"-36" apart and 6"-12" between plants in rows (100-200 plants per 100 feet of row). Double or single rows on plastic-lined beds are common. Flat culture is used on muck soils.

Field Culture

Celery is a long-season crop that grows best under cool conditions (60°-75°F) with an ample and uniform supply of water. It may be necessary to irrigate when transplanting and once or twice each week thereafter.

Harvest and Storage

Cut the whole celery plant instead of individual petioles. Older outer petioles may need to be removed to provide a fresh tender crop. Freshly harvested celery may have a bitter flavor, which can be improved by storing at 32°-34°F for a few days. Chilling injury can result if the storage temperature falls below 32°F. Celery left in the field beyond peak will continue to mature and deteriorate in quality.

Celeriac holds well in the field. It is harvested and trimmed of roots and stalks when tubers are 4" in diameter. Celeriac may be stored for 3-6 months if kept at 32°-34°F and 95% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Anthracnose Leaf Curl (*Colletotrichum fioriniae* and *C. nymphaeae*)

Formerly known to be caused by *Colletotrichum acutatum*, the pathogen has now been identified to be caused by *Colletotrichum fioriniae* and *C. nymphaeae*. *Colletotrichum fioriniae* also causes bitter rot in apples while *C. nymphaeae* also causes strawberry anthracnose. Common lambsquarters, redroot pigweed, yellow nutsedge, oakleaf goosefoot, and common groundsel all harbor celery anthracnose without clearly expressing symptoms. Symptoms on celery include curled leaves, occasional discoloration of leaf margins, twisted petioles, and lesions on petioles. Leaves remain green but often appear fan-like and curl downward. Leaf curl is often the most prominent symptom observed and can resemble injury from growth regulator type (i.e. 2,4-D) herbicides. In advanced stages, the disease can resemble Black Heart, which is a physiological disorder caused by low calcium assimilation. Celery leaf curl thrives under warm, wet conditions. Rapid growth occurs when temperatures are 77°-86°F, with substantially more disease development at 86° than 77°F. Temperatures as cool as 60°F will support fungal growth and spread, but field progression will be slow. This disease may be seedborne. Start with clean flats and growth medium. Scout plants twice a week for symptoms; remove and destroy affected plants. Removal of crop debris

Plant Nutrient Recommendation According to Soil Test Results for Celery and Celeriac

CELERY AND CELERIAC	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	100	180	120	30-60	0	240	180	45-90	0
Sidedress 3-4 weeks after setting	40	0	0	0	0	0	0	0	0
Sidedress 7-8 weeks after setting	40	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	180	180	120	30-60	0	240	180	45-90	0

after harvest and plowing under crop residue will limit pathogen carry over from year to year. A 3- to 4-year crop rotation with non-host plants should be followed. Avoid working the fields when the plants are wet, work in fields with a history of the disease last, and power wash equipment between fields. Research has shown that the strobilurin fungicides are most effective, however, be careful to rotate as resistance can develop quickly in this group.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A. PHI 0d, REI 4h, Group 11. Do not apply more than one application before alternating with a non-Group 11 fungicide.

***Gliocladium catenulatum* strain J1446 (PVent^{OG}):** PHI 0d, REI 4h. See label for instructions.

pyraclostrobin (Cabrio EG): 12-16 oz /A, PHI 0d, REI 12h, Group 11. Do not make more than 2 sequential applications of fungicides in this group, and no more than 64 oz per year.

pyraclostrobin plus boscalid (Pristine): 10.0 to 15.0 oz/A. PHI 0d, REI 12h, Groups 7 & 11.

■ **Leaf Blight (*Cercospora apii* (Early Blight) or *Septoria apicola* (Late Blight))**

Use certified, disease-free seed or treat seed with hot water or fungicides. Practice careful sanitation in transplant greenhouses or rotate ground seedbeds. Irrigate early in the day to allow foliage to dry quickly. Use wider plant spacing and/or raised beds to improve air circulation. Plant resistant or tolerant varieties where available. Apply fungicides based upon a disease forecasting system.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not apply more than one application before alternating with a non-Group 11 fungicide.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.7 pt/A; PHI 7d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus propiconazole (Quilt): 14.0 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 2 to 3 pt/A; PHI 7d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

penthiopyrad (Fontelis): 14 to 24 oz/A; PHI 3d, REI 12h, Group 7.

propiconazole (Tilt): 4.0 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin plus boscalid (Pristine): 10.0 to 15.0 oz/A; PHI 0d, REI 12h, Groups 7 & 11.

trifloxystrobin (Flint): 2 to 3 oz/A; PHI 7d, REI 12h, Group 11. Do not make more than one application before alternating with a non-Group 11 fungicide.

■ **Basal Stalk Rot (*Rhizoctonia solani*)**

A 2-year rotation is recommended to prevent buildup of disease-causing organisms. Avoid crops such as alfalfa and legume cover crops which can increase disease risk. Avoid cultivating late in the season. Maintain storage conditions at 50°F.

azoxystrobin (Quadris): 0.4 to 0.8 fl oz/1,000 row feet; PHI 0d, REI 4h, Group 11 (see label for clarification). Apply in a 7" band in-furrow or shortly after emergence. After emergence, direct application to stem.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.7 pt/A; PHI 7d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

chlorothalonil (Bravo Weather Stik): 2.0 to 3.0 pt/A; PHI 7d, REI 12h, Group M5.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

■ **Pink Rot (*Sclerotinia sclerotiorum*)**

Do not plant seed contaminated with sclerotia or plant into severely infested fields. Irrigate in the morning or with subsurface drip systems to promote drier soil. Rotate with non-hosts. Soil sterilization with chemicals, heat, or steam can reduce sclerotia in the soil.

***Bacillus amyloliquefaciens* F727 (Stargus^{OG}):** 2 to 4 qt/A; PHI 0d, REI 4h, Group 44. Apply preventatively in a minimum of 50 gallons of water/A.

boscalid (Endura): 8.0 to 9.0 oz/A; PHI 0d, REI 12h, Group 7.

chlorothalonil (Bravo Weather Stik): 3.0 pt/A; PHI 7d, REI 12h, Group M5. For disease suppression.

***Coniothyrium minitans* (Contans WG^{OG}):** 1.0 to 4.0 lb/A in 20-50 gal water; REI 4h, Group not applicable. Spray on soil surface and incorporate into top 2" soil. Apply in fall or 3-4 months prior to planting.

cyprodonil + fludioxonil (Switch): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 12. Make first application at thinning and once more two weeks later.

***Ulocladium oudemansii* (BotryStop^{OG}):** 2.0 to 4.0 lbs/A; REI 4h, Group not applicable. Begin application when conditions are conducive to disease development.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Aphids**

See Pepper section for more information about green peach aphid.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 21d, REI 24h, Bee: H, Group 1B. Green Peach Aphid. Tops must be removed before use; do not use tops for food or feed. Celery only.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A. Celery only.

afidopyropen (Versys): 1.5 fl oz/A; PHI 0d, REI 12 h, Bee: L, Group 9D.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A celery, 3.2 to 3.8 celeriac; PHI 1d, REI 12h, Bee: H, Group 3A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Green peach aphid only. Celery only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For control of green peach and suppression of potato aphid only. Celery only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4 h, Bee: H, Group 28.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 7d foliar, 21d soil, REI 12h, Bee: H, Group 4A. Suppression of green peach and potato aphids. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. Celery only.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d celery, 3d celeriac, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A for foliar application, 21 to 28 oz/A for soil application (celery only); PHI 1d foliar, 21d soil, REI 4h, Bee: L, Group 4D.

imidacloprid (Admire Pro): 4.4 to 10.5 oz/A soil; 1.3 oz/A foliar celery; PHI 45d soil, 7d foliar, REI 12h, Bee: H, Group 4A. Foliar applications allowed for celery only.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications and/or use a companion insecticide.

malathion (Malathion 57EC): 1.5 pt/A; PHI 7d, REI 12h, Bee: H, Group 1B. Celery only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Celery only.

pymetrozine (Fulfill): 2.75 oz/A; PHI 7d, REI 12h, Bee: L, Group 9B. Celery only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility. Celery only.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; PHI 3d celery, 7d celeriac, REI 12h, Bee: H, Group 4C. Application to celeriac foliage and celery only.

sulfoxaflor (Transform WG): 0.75 to 1.5 oz/A; PHI 7d, REI 24h, Bees: H, Group 4C. Celeriac only.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

tolfenpyrad (Torac): 17 to 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A. Except lettuce aphid. Celery only.

■ Cabbage Looper and Imported Cabbageworm

See Cabbage and Other Brassica Crops for more information on cabbage looper and imported cabbageworm.

acephate (Orthene 97): 1 lb/A; PHI 21d, REI 24h, Bee: H, Group 1B. Tops must be removed before use; do not use tops for food or feed. Cabbage Looper on celery only.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A looper, 0.25 to 1 lb/A ICW; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.4 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Celery only.

buprofezin & flubendiamide (Vetiva): 12 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28. Celery only.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 14d, REI 12h, Bee: H, Group 1A. Imported cabbage worm only.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through chemigation and as a foliar spray. For drip application, must be applied uniformly in the root zone. For foliar application an adjuvant may be used. Cabbage looper only.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 10 to 17 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Cabbage looper on celery only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Celery only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Cabbage looper on celery only.

flubendiamide (Belt SC): 1.5 oz/A; PHI 1d, REI 12h, Bee: L, Group 28. Celery only.

indoxacarb (Avaunt): 3.5 oz/A; PHI 3d, REI 12h, Bee: H, Group 22. Cabbage looper on celery only.

methomyl (Lannate* LV): 3 pt/A; PHI 7d, REI 48h, Bee: H, Group 1A. For cabbage looper on celery only.

methoxyfenozide (Intrepid 2F): 4 to 10 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Use lower rates when plants are small or infestations are light.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Cabbage looper on celery only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Celery only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils. Cabbage looper only.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 1d celery, 3d celeriac, REI 4h, Bee: M, Group 5. Do not apply to celery seedlings intended for transplant.

tebufenozide (Confirm 2F): 6 to 8 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Use higher rate for late-season applications or for heavy infestations. Low toxicity to natural enemies. One pint of adjuvant per 100 gallons of spray mixture is recommended. Celery only.

tolfenpyrad (Torac): 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A. Suppression of cabbage loopers only. Celery only.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A for ICW; 3.4 to 4.3 oz/A for CL; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Leafminers (*Liriomyza* species)

There are several species of leafminers in the genus *Liriomyza*, including the serpentine leafminer (*Liriomyza trifolii*), the vegetable leafminer (*L. sativae*), pea leafminer (*L. huidobrensis*) and cabbage leafminer (*L. brassicae*). Most of these species feed on a very broad range of vegetables, weeds, flowers and wild plants. Cabbage leafminer is most often found on brassicas, and rarely on other crop groups. In southern regions of the US, *Liriomyza* leafminers can be pests of basil, beans, cabbage and other brassicas, celery, lettuce, pepper, eggplant, tomato, and cucurbits. In New England, especially with greater use of selective insecticides that conserve natural enemies, these leafminers rarely reach pest status.

Adults in this group are small (2.0 to 2.5mm), hump-backed, clear-winged flies with black and yellow markings. Females lay eggs within the leaf, and larvae feed between the upper and lower surfaces of the leaf, creating winding mines. When full grown, larvae emerge and form a brown pupa about the size of a rice grain on the leaf or in the soil. The life cycle takes 3 to 4 weeks depending on temperature. Mines render the leaf unmarketable, reduce photosynthetic capacity, and provide entry for pathogens. Leafminers generally are controlled by naturally occurring parasites unless disrupted by broad-spectrum insecticide applications. There is also a commercially available biological control, the tiny wasp parasitoid, *Diglyphus isaea*, used against *Liriomyza* leafminers in a wide range of crops; it works best in warm weather.

In the southern and western US, pesticide resistance has become a problem. Avoid obtaining transplants from outside the Northeast, which could carry resistant strains. Control broadleaf weeds in and around the crop. Incorporate infested crop residues after harvest to prevent emergence and movement to new plantings. Most importantly, use selective insecticides on other pests to conserve natural enemies. Scouting methods include catching adults on yellow sticky traps placed in mid or lower canopy, or trapping pupae in trays underneath the plants. Counting mines is a good index of past activity, but mines may be vacant and searching for larvae in mines is time consuming. Treatment may be warranted if damage is delaying growth or marketable parts of the plant are being damaged, and adult fly populations are increasing.

See the beets and chard section for leafminers that occur on the *Amaranthaceae* (spinach, beets, chard) crop group.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant. Celery only.

chlorantraniliprole (Coragen): 5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through chemigation and as a foliar spray. For foliar application an adjuvant may be used. Celery only.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Celery only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Celery only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

cyromazine (Trigard): 2.66 oz/A; PHI 7d, REI 12h, Bee: M, Group 17. Celery only.

dimethoate (Dimethoate 4EC): 1 pt/A; PHI 7d, REI 48h, Bee: H, Group 1B. Celery only.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. Celery only.

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Suppression only. Celery only.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. May need to make repeated applications and/or use a companion insecticide.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Celery only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Celery only.

spinetoram (Radiant SC): 6 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Control may be improved with the addition of an adjuvant to the spray mixture.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A celeriac, 6 to 10 oz/A celery; *PHI 1d celery, 3d celeriac, REI 4h, Bee: M, Group 5.* Control may be improved with the addition of an adjuvant. Do not apply to celery seedlings intended for transplant.

■ Mites

See Eggplant for more information about mites.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant. Use high rate on celeriac.

***Chromobacterium subsugae* (Grandevo^{OG}):** 2 to 3 lb/A; *PHI 0d, 4h REI, Bee: M.*

malathion (Malathion 57EC): 1.5 pt/A; *PHI 7d, REI 12h, Bee: H, Group 1B.* Celery only.

***Metarhizium anisopliae* Strain F52 (Met 52 EC):** 40 to 80 oz/100 gal soil, 8 to 64 oz/A foliar; *PHI 0d, REI 0h, Bee: L.* Celery only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Celery only.

sulfur (Microthiol Dispers^{OG}): 4 to 6 lb/A; *REI 24h, Bee: L.* No IRAC classification. Celery only.

■ Tarnished Plant Bug (*Lygus lineolaris*)

See Lettuce for information about tarnished plant bug. Bugs may feed on leaf petioles or produce lesions or small sunken cavities on stalks. Injury to the inner growing tip can cause foliar discoloration and tissue destruction that is similar to the physiological condition known as ‘blackheart’. If your crop is near weedy fallow fields or alfalfa, scout weekly from when celery is 4" tall until 3 weeks before harvest to detect TPB and injury, as the economic injury level is low. Treat at 2 to 4 bugs per 20 plants. Control weeds in and around the field. Do not plant near legume crops that may be harvested during the season or TPB may migrate to celery.

beta-cyfluthrin (Baythroid* XL): 2.4 to 3.2 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.* Celery only.

carbaryl (Sevin XLR plus): 1 to 2 qt/A; *PHI 14d, REI 12h, Bee: H, Group 1A.*

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. May need to make repeated applications and/or use a companion insecticide.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; *PHI 0d celery, 3d celeriac, REI 12, Bee: L, Group 9C.*

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Celery only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Celery only. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): *REI 12h, Group 8.* Apply 5 to 6 qt/A. Celery only. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours or application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Celery only. Rate based on soil texture and crop, see label for details. Apply 1 to 2 pt/A of Treflan HFP as a soil-incorporated treatment. Treflan HFP may be applied to direct seeded or transplant celery before planting, at planting, or immediately after planting. Little or no control of ragweed, mustard, and nutsedge.

■ Herbicides Used Pre- and Postemergence to Weeds

prometryn (Caparol 4L): *PHI 30d for celery, PHI 60d for celeriac, REI 12h, Group 5.* Primarily controls annual broadleaf weeds. Annual grasses may only be suppressed. Do not use on sand or loamy sand. Do not apply if crop is under water stress. Do not apply within 2 weeks after an application of an herbicidal oil, such as “carrot” oil.

For celery: Can be used pre- or postemergence. To avoid crop injury, make either 1 preemergence or 1 postemergence application (not both) per crop. For preemergence use, apply 2.4 to 3.2 pt/A at planting or shortly after planting but before the crop emerges. For postemergence use, 1.6 to 2 pt/A after the crop has 2 to 5 true leaves. May be applied over the top of the crop. Apply before weeds are 2" tall.

For celeriac: Do not exceed 4 pt/A per crop cycle. Make a single broadcast application at 1.6 to 4 pt/A in a minimum of 20 gal of water per acre after the crop has 6 to 8 leaves. Application may be made over the crop. Use the lower rate on coarse-textured soils and soils low in organic matter. Apply before weeds are 2" tall.

Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 30d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

linuron (Lorox DF): PHI 45d celery, PHI 60d celeriac, REI 24h, Group 7. Apply as a single application of up to 3 lb/A after the celery or celeriac has been transplanted and establish, but before the crop is 8" tall. For use in celery, only use on celery grown on muck soils. Do not apply when temperatures exceed 85 degrees F. Do not apply as a tank mixture with surfactants, nitrogen or fertilizer solution, or other pesticides, as injury to the crop may result.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Celery only. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Celery only. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PHYSIOLOGICAL DISORDERS

Black Heart

Blackheart is a physiological reaction of celery associated with poor calcium assimilation that occurs in most celery growing regions and is closely linked to growing conditions. Significant losses have been reported in Florida, California, Texas, Utah and Wisconsin. If conditions favorable for the

development of blackheart persist the entire crown may be destroyed in a few days. In minor cases, the plants may recover or seem to recover, although symptoms can return. Symptom development is much more severe as plants approach maturity. The appearance of symptoms is closely linked to fluctuating water levels and available calcium. Environmental conditions that favor rapid growth such as heavy rain or irrigation subsequent to drought favor symptom development. High nitrogen, potassium, and sodium levels may also play a role. Certain celery cultivars are more susceptible to blackheart. Blackheart is prevented by ensuring steady plant growth, avoiding wide fluctuations in moisture and nutrients. Drench applications of soluble calcium can lessen or prevent the development of blackheart. Plant celery cultivars that are not prone to the syndrome. Drip irrigation which provides more even moisture levels can help reduce risk.

CORN: ORNAMENTAL AND POPCORN

Ornamental corn varieties are mostly flint type corns (*Zea mays indurata*) with hard variously colored kernels. While originally grown as food, today they are grown primarily for ornamental purposes. Popcorn (*Zea mays everta*) is a variant of flint corn that can be popped. Broom corn (Sorghum vulgare), which is commonly grown as an ornamental, is not actually corn, but rather a relative of the sorghum grown for syrup and seed.

All of these ornamental corns will grow in any sunny, well-drained, fertilized soil that will grow field or sweet corn. Adequate moisture, especially after the ears form, is necessary. Isolation from other types of corn is suggested. Bird damage can be a concern. Use nutrient and pest management recommendations for sweet corn.

Types and Varieties

Hybrids are available, but most ornamental corn varieties are open-pollinated. Seed can be saved if it is isolated from other types of corn including sweet corn and dent corns. Ornamental popcorn should be considered for miniature decorative ears and the dual purpose of popping.

Ornamental Corn and Popcorn Varieties	
<p>Full-sized ornamental</p> <p>Autumn Splendor Bloody Butcher Earth Tones Dent Fiesta F1 Indian Art 104 Indian Art Cranberry Painted Mountain Rainbow</p>	<p>Miniature ornamental</p> <p>Carousel Indian Fingers Little Jewels</p>
<p>Broom corn</p> <p>Colored Uprights Red Broom Corn Texas Black</p>	<p>Popcorn</p> <p>Cherry Berry Red Strawberry Corn White Cloud Mini Blue Robust 997 (R997)</p>

Soil Fertility

See sweet corn Soil Fertility, page 167.

Planting

Because of its hard seed coat, ornamental corn should be planted early to allow for full maturity on the stalks. Plant to 9" to 10" within rows and 30" to 36" between rows at 1 to 1.5" deep. Keep ornamental corn away from sweet corn or popcorn that pollinates at the same time as ornamental corn.

Harvest

Harvest when the kernels are hard and bright and the husks are brown. Husk and hang to dry. Do not box or bag ears when they are first harvested, or they may mold. Mold may occur on the husk and the ear if proper handling and storage techniques are not used.

CORN, SWEET

Sweet corn (*Zea mays* convar. *saccharata* var. *rugosa*) is a warm-season crop and one of the major vegetables grown in New England. It is an extremely popular crop for roadside stand and farmers' market sales as well as for wholesale markets.

Sweet corn grows on a wide range of soil types. Early planting should be on light, well-drained soil in a warm, sheltered location. Heavier soils are best for the main crop. Plowing under corn stalks and cover crops to maintain high levels of organic matter in soils is recommended for best crop production. Irrigation may only be necessary in dry weather, particularly on light soils, and especially as silking starts.

Types and Varieties

Sweet corn varieties are categorized by their genotype. The most common types are normal/sugary (su), sugar enhanced (se), and supersweet/shrunken (sh₂). Other newer varieties include sweet breeds, synergistic, sweet genes, or improved supersweets which have a combination of genes.

su "Normal" or "Sugary"

Standard hybrid sweet corn is a mutant type of corn that differs from field or dent corn by a mutation at the sugary (su) locus. This type accumulates about twice as much sugar than field corn.

se Heterozygous Sugary Enhanced or "Modified Sugar" or "Everlasting Heritage (EH)"

se+ Homozygous Sugary Enhanced

There are two distinct groups within the cultivars containing the "se" gene, which increases sugar levels above those found in "su" varieties. The "homozygous se" or se+ cultivars have higher sugar levels in 100% of their kernels. Cultivars that are "heterozygous se" have higher sugar levels in 25% of their kernels; the other 75% contain the normal "su" gene with lower sugar levels. Thus, "se+" cultivars are usually sweeter than "se" cultivars.

- Sugar conversion to starch is about the same rate as standard sweet corn. Refrigeration is essential to maintain quality.
- Isolation not required, but desirable. Note directions on seed tag label.
- Kernels tender and creamy.
- Tip cover weak on some varieties

sh₂ "Super Sweet" or "Extra Sweet"

- Sugar content twice as high as standard sweet corn.
- Slow sugar conversion to starch so quality will hold 7-10 days. Refrigeration suggested to extend quality.
- Isolation is required from all other types of corn. Note directions on label.
- Kernels can be somewhat tough or crunchy.
- Does not germinate well in cold, wet soil. Plant after soil temperatures exceed 65°F and be sure there is adequate soil moisture. Adjust planting depth for soil conditions and soil type. Seed of the "sh₂" type is light-weight, wrinkled, and fragile and should be handled gently to prevent damage.

syn "Synergistic"

These include synergistic or improved supersweets such as Sweet Breed and Sweet Genes. These varieties have combinations of su, se, se+, or sh₂ genes. Synergistic varieties having the sh₂ gene may be grown with other "Super Sweet" varieties, but must be isolated from "se" and "su" types to achieve best quality.

aug "Augmented Shrunkens"

Augmented Shrunken sweet corns are a new type of shrunken corn types. They contain the "sh₂" gene, but kernels of augmented shrunken are more tender, like "se" varieties. Augmented shrunken varieties should be hand harvested because their tender kernels will likely be damaged by machine picking. These varieties need to be isolated from normal, "se" and synergistic hybrids. Additionally, they have the same seed vigor problems as supersweet varieties and should only be planted under optimal conditions.

Mirai™

Mirai™ sweet corn varieties carry two copies of all three sweet corn genes: su, se and sh₂. They have all tender supersweet kernels and, like the augmented shrunken varieties, need to be hand-harvested. Mirai varieties also need optimal soil conditions for seedling establishment. Mirai types do not require isolation to avoid starchy kernels, but isolation from other sweet corn types will assure best quality.

Bt Hybrids

These are genetically-modified (GM) varieties that are protected from European corn borer, and to a lesser extent, fall armyworm and corn earworm caterpillars because they express the protein toxin of the bacteria *Bacillus thuringiensis*. They are currently available as super sweet (sh₂) or as synergistic "TripleSweet" varieties, composed of 75% "se" and 25% "sh₂" kernels. In the synergistic varieties, the Bt toxin is expressed in the "se" kernels, the stalks, leaves, tassels and fresh silk. Bt varieties are still susceptible to attack from flea beetles, cutworms, aphids, sap beetles, high levels of corn earworm and soil-dwelling insects. Bt seed costs more than the seed of other sweet corn varieties and currently comes with a list of resistance management strategies with which to comply. These varieties may reduce the time, energy and expense associated with insect control and may simplify sweet corn pest management. There are many other less obvious potential risks and benefits that may be associated with the use of this technology. GM sweet corn varieties, including all Bt varieties, are not allowed in

organic production. Growers in Maine must be certified to grow *Bt* corn. Contact the Maine Board of Pesticides Control for more information.

Sweet Corn Varieties

VARIETY	TYPE	COLOR	WILT	RUST	MDMV
Sweet Chorus (67)	syn	Bi	L	M	M
Sweetness (68)	syn	Bi	-	-	-
Latte (68)	syn	Bi	M	M	-
Vitality (68)	se	Bi	-	-	-
Espresso (70)	syn	Bi	M	M	-
Mirai 308BC (70)	mirai	Bi	-	-	-
Harris 1001 (72)	se	Bi	M	-	-
Temptation (72)	se+	Bi	-	-	-
Reflection (72)	syn	Bi	-	M	-
Cuppa Joe (73)	syn	Bi	M	M	-
XTH 2170 (73)	sh ₂	Bi	M	-	-
Mirai 336BC (73)	mirai	Bi	-	M	M
Sweet Rhythym (73)	syn	Bi	M	L	-
Anthem XR (73)	sh ₂	Bi	L	H	-
Charisma (74)	se	Bi	M	M	-
Fanstastic (74)	sh ₂	Bi	-	-	-
XTH 274A (74)	sh ₂	Bi	M	-	-
Sweet Ice (74)	syn	W	M	L	L
Kristine (74)	syn	Bi	M	M	-
Mystique (75)	se+	Bi	H	M	L
SC1102 (75)	syn	Bi	-	-	-
Sparkler (75)	syn	Bi	-	-	-
Mirai 301BC (76)	sh ₂	Bi	M	M	-
Awesome (76)	sh ₂	Bi	M	-	-
Luscious (77)	se	Bi	-	-	-
Accord (78)	se	Bi	-	-	-
Legion (78)	sh ₂	Bi	M	M	M
Pow Pow (78)	syn	Bi	-	-	-
Essence (78)	syn	Bi	M	M	-
Providence (79)	syn	Bi	-	M	-
Montauk (79)	syn	Bi	M	-	-
Delectable (80)	se+	Bi	M	H	L
Precious Gem (80)	se+	Bi	M	M	L
Primus (81)	sh ₂	Bi	M	M	-
BC 805 (82) *	se	Bi	-	H	-
Jackpot (82)	se+	Bi	M	M	-
Silver King (82)	se+	W	M	M	-
Argent (83)	se	W	H	M	L
Incredible (85)	se+	Y	H	-	-
Cameo (84)	se	Bi	M	M	-
Silver Queen (94)	su	W	H	L	L

The number in parentheses is the approximate number of days to maturity from seeding. H, M, L: High, medium or low resistance or tolerance to the following diseases - Wilt: Stewart's wilt, Rust: Common rust, MDMV: Maize dwarf mosaic virus. Other codes: mirai: mirai, su: normal sugary, se: sugar enhanced, se+: sugar enhanced homozygous, sh₂: supersweet/shrunken, syn: has some combination of su, se and sh₂ genes, Y: yellow kernels, W: white kernels, Bi: bicolor, *: *Bt* hybrid

Soil Fertility

Apply lime according to soil test to maintain soil pH between 6.5 and 6.8.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Apply no more than 80-100 pounds per acre combined weight of actual nitrogen and potassium applied 2" on the side and 2" below the seed as a band. Higher amounts of nitrogen and potash applied as a concentrated band may damage corn seed and young plants.

Planting

Effective isolation is required in some cases with the present types of sweet corn on the market. Isolation is affected by distance, wind direction, time of pollen shed and silking, and blocking. From a practical standpoint, the same methods are needed as when separating white and yellow varieties. Field experience indicates isolation can be managed more easily than initially expected.

Plant early varieties 8"-10" apart within rows with 30"-36" between rows. Plant main season varieties 10"-12" apart within rows with 36" between rows. This requires 10-15 lb of seed/A (1-2 oz per 100 feet of row) or 17,500-26,000 seeds/A for early and 14,500-17,500 for main season varieties. Match seed size to seed plate. Read seed container or contact the company regarding appropriate plate sizes.

First plantings are made in early April in southern New England and in May in northern New England. Growers planting in cold soils run the risk of erratic germination and poor stands. Avoid planting while soil temperature is lower than 55°F. If soil temperature is below 60°F, it is advisable to plant treated seed. If you are planting untreated seed, wait until the soil temperature is at least 65°F. Most seed companies perform cold germination tests of their seed. If in doubt about the suitability of a corn variety for early planting, ask your seed dealer about the low temperature germination and vigor of the seed.

Clear plastic mulch raises soil temperature and can be used for the earliest plantings. This can allow for earlier planting and provide corn 7-10 days earlier than non-mulched corn. Apply fertilizer and herbicides, and plant seed before laying the plastic over seeded rows. Two rows 18"-24" apart are usually planted under each strip of 5'-wide plastic. To avoid plant injury, do not let temperatures beneath the plastic get too high (90°F or more). When such conditions occur, or when the plants reach 4" in height, cut slits in the plastic to allow heat to escape and plants to grow through. Remove the plastic completely by the time the corn is knee high to facilitate removal and permit cultivation.

Spunbonded row covers offer a potential three-way benefit for early sweet corn production. Maturity is increased by 5-10 days, yields are generally increased by 15%-20%, and the first generation corn borer can be controlled if the covers are left on until after the peak of the first generation corn borer flight. They can also be used to pre-warm the soil before planting. They can be removed to allow planting and then replaced. Weight cover edges with soil or sand bags to prevent damage by gusty winds, but leave adequate slack for plant growth to the tassel stage.

Transplanting Sweet Corn

Transplanting sweet corn offers some advantages to growers over direct seeding, including better stands, earlier harvest, and less dependence on pre-emergent herbicides. However, transplanting is more labor intensive, costly and requires attention to detail in order to be successful.

Corn can be seeded by hand, or a simple, inexpensive drop seeder can be built to fit the size of tray to be used. 98-128 cell trays work best (a 128 cell tray requires 82 trays per acre). The smaller plug trays require less media, but are more easily root-bound. Fill trays with a peat-based potting mix, and plant one or two seeds per cell. Place trays on tables or benches to prevent plants from rooting in the ground. Greenhouse temperatures should be set for 65-degree days and 60-degree night temperatures. Transplants should be ready in about 14-18 days, and should be hardened off before planting in the field, by placing the trays outdoors and limiting water for a few days. Fertilizer should be banded prior to planting, or applied as a liquid at planting. The plants should have good, cohesive roots that come out of the tray with relative ease. They may be planted by hand or machine. Plants can be spaced 14-16 inches apart within rows, with about 3 feet between rows. Floating row covers should be placed over the corn for the first two to three weeks after planting. These can be pulled back to allow cultivation. Transplanting and row covers should bring corn to maturity about two weeks earlier than direct seeding. Not all varieties perform well in this system. Test your favorite early-mid maturity varieties in small trials before committing large amounts of trays and greenhouse space to them.

Harvesting and Storage

The sweetness and tenderness of sweet corn will deteriorate rapidly after harvest. Sweet corn should be cooled immediately after harvest and kept at 32°F to retain optimum freshness. The crop is best harvested early in the morning when there is less field heat. Harvesting at the proper stage (milk stage) is critical in maintaining quality. During the summer, sweet corn will be at the proper stage only 1-2 days. It will approach maturity 16-22 days after silking and should be picked daily. As the kernel passes the prime harvest time, sugars convert to starch and the pericarp becomes tough. Supersweet varieties retain their sweetness longer than su and se varieties; extra tender varieties maintain eating quality even longer.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Leaf Spots (*Helminthosporium*, *Cochliobolus*, *Cercospora*)

Plant resistant varieties. Improve air circulation by plant spacing and site selection. Plow under crop debris promptly after harvest to speed decomposition. Fungicide rotation is critical for prevention of resistance development—do not make back-to-back applications of products with active ingredients from the same group.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 7d, REI 4h, Group 11.

azoxystrobin & propiconazole (Quilt): 7 to 14 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 0.75 to 2 pt/A; PHI 14d, REI 12h, Group M5. Do not apply to sweet corn to be processed. Not labeled for popcorn.

fluxapyroxad plus pyraclostrobin (Priaxor Xemium): 4 to 8 fl oz/A; PHI 7d (sweet), PHI 21d (popcorn), REI 12h, Groups 7 & 11.

mancozeb (Dithane F45): 1.2 qt/A; PHI 7d, REI 24h, Group M3.

propiconazole (Tilt): 2.0 to 4.0 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin (Headline): 6 to 12 fl oz/A; PHI 7d, REI 12h, Group 11.

pyraclostrobin plus metaconazole (Headline AMP): 10.0-14.4 fl oz/A; PHI 7-20d (see label), REI 12h, Groups 11 & 3.

trifloxystrobin plus propiconazole (Stratego): 10 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

■ Northern Corn Leaf Blight (*Exserohilum [Helminthosporium] turcicum*)

Northern corn leaf blight is an emerging problem on farms up and down the Connecticut River Valley. Northern corn

Plant Nutrient Recommendation According to Soil Test Results for Sweet Corn

SWEET CORN	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Early Season Sweet Corn									
Broadcast and Incorporate	0	100	40	0	0	150	90	0	0
Band Placement at Planting	40	40	40	40	0-40*	30	30	0-30	0
Sidedress	60-90**	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	100-130	140	80	40	0-40*	180	120	0-30	0

*Phosphorus is not necessary for warm soils.
**Before sidedressing use a nitrate test to determine the need for additional N

leaf blight can develop very rapidly resulting in a complete blighting of leaves. *E. turcicum* overwinters in and on leaf debris and conidia can be spread long distances by wind. Under the right conditions (prolonged leaf wetness, extended rainy and humid weather, moderate temperatures), conidia are produced abundantly and disease spread is rapid. Reduce primary inoculum by crop rotation and tilling under of crop residue. Evidence suggests more severe disease in reduced-till systems; 1-year rotations are suggested for conventional practices and 2-year rotations for reduced-till. Resistant hybrids of all maturity groups are available. Lesions may vary in morphology when certain genes for resistance to this disease are present. The presence of these genes results in long, yellow, linear streaks that resemble the symptoms of Stewart's Wilt. Growing susceptible varieties will cause the resistance of nearby resistant varieties to break down. Fungicide rotation is critical for prevention of resistance development—do not make back-to-back applications of products with active ingredients from the same group.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 7d, REI 4h, Group 11.

azoxystrobin plus propiconazole (Quilt): 7.0 to 14 .0fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 0.75 to 2 pt/A; PHI 14d, REI 12h, Group M5. Do not apply to sweet corn to be processed. Not labeled for popcorn.

fluxapyroxad plus pyraclostrobin (Priaxor Xemium): 4.0 to 8.0 fl oz/A; PHI 7d (sweet), 21d (popcorn), REI 12h, Groups 7 & 11.

mancozeb (Dithane F45): 1.2 qt/A; PHI 7d, REI 24h, Group M3.

propiconazole (Tilt): 2.0 to 4.0 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin (Headline): 6.0 to 12.0 fl oz/A; PHI 7d, REI 12h, Group 11.

pyraclostrobin plus metaconazole (Headline AMP): 10.0 to 14.4 fl oz/A; PHI 7-20d (see label), REI 12h, Groups 11 & 3.

trifloxystrobin plus propiconazole (Stratego): 10.0 fl oz/A; PHI 14d (sweet), 30d (popcorn), REI 12h, Groups 11 & 3.

■ Rust (*Puccinia* species)

The common rust fungus that occurs on sweet corn does not overwinter in the Northeastern United States; each year it is blown up from the south. Rust can cause significant reduction in ear weight and yield on susceptible varieties. Corn is more susceptible to infection prior to tasseling so later maturing plantings may have higher losses. Fungicides will control this disease but should be applied before tasseling. Apply fungicides when 80% of the plants show 1 or more pustules per leaf. Resistant varieties are available. Fungicide rotation is critical for prevention of resistance development—do not make back-to-back applications of products with active ingredients from the same group.

azoxystrobin & propiconazole (Quilt): 10.5 to 14 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

benzovindiflupyr (Trivapro A): 4 fl oz/A; PHI 7d, REI 12h, Group 7.

chlorothalonil (Bravo Weather Stik): 0.75 to 2 pt/A; PHI 14d, REI 12h, Group M5. Do not apply to sweet corn to be processed. Not labeled for popcorn.

fluxapyroxad plus pyraclostrobin (Priaxor Xemium): 4 to 8 fl oz/A; PHI 7d (sweet), 21d (popcorn), REI 12h, Groups 7 & 11.

mancozeb (Dithane F45): 1.2 qt/A; PHI 7d, REI 24h, Group M3.

propiconazole (Tilt): 4.0 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin (Headline): 6.0 to 12.0 fl oz/A; PHI 7d, REI 12h, Group 11.

pyraclostrobin plus metaconazole (Headline AMP): 10.0 to 14.4 fl oz/A; PHI 7-20d (see label), REI 12h, Groups 11 & 3.

trifloxystrobin plus propiconazole (Stratego): 10 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

■ Seed Decay

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

thiram (Thiram 42-S): 5.0 lb/100 lb seed; REI 12h, Group M3.

■ Common Smut (*Ustilago maydis*)

Smut occurs sporadically from one season to another but usually less than 2% of the plants are affected. The disease is favored by dry conditions when temperatures are between 80°F and 90°F and nitrogen fertility is high. Injury due to cultivation, hail or wind-blown sand can increase the incidence of disease when environmental conditions are favorable. Fungicides will not provide effective control of common smut.

■ Stalk Rots (*Gibberella*, *Stenocarpella*, *Macrophomina*, *Colletotrichum*, *Fusarium*)

Fungal stalk rots continue to be serious diseases of corn. Their occurrence and severity vary from year to year. Stalk rots cause losses by causing premature plant death, difficulties with mechanical harvesting, and ear rot due to contact of ears with the soil. Factors that influence stalk rot include the susceptibility of the hybrids, weather conditions, the presence of foliar diseases, plant densities, insect damage, moisture availability, soil fertility, and tillage practices. Soil fertility, tillage, and plant density can be adjusted to provide control. Stalk rot is more severe and more common where soil fertility is high. Nitrogen (N) levels can both increase and decrease stalk rot; an excess of N in relation to potassium (K) increases stalk rot. A balanced and continuous supply of N reduces the occurrence of stalk rot. Adequate K reduces stalk rot severity by strengthening cell walls. In general, corn debris left on the surface of the soil harbors many foliar diseases that increase stalk rot by reducing photosynthesis. As the population of plants increases, the incidence and severity of stalk rot also increase, especially in susceptible hybrids. Control is most successfully achieved through the use of resistant hybrids. Cultural practices such as balanced fertility, proper plant spacing, and reduction of other plant stresses, such as insect damage, can also reduce stalk rot.

■ Stewart's Wilt (*Pantoea [Erwinia] stewartii*)

This bacterial disease is spread by the corn flea beetle and is particularly damaging when susceptible varieties are planted following mild winters. *P. stewartii* overwinters in the

alimentary tract of adult corn fleas beetles, not in the soil or in plant debris. Severity of Stewart's Wilt depends on three factors: the winter temperatures prior to planting, the amount of disease the previous season, and cultivar susceptibility. If cold winter temperatures occur, fewer flea beetles survive to transmit the disease. The amount of disease in the previous season determines the percentage of emerging beetles carrying the bacterium. Hybrids with greater levels of resistance can tolerate more infection with less yield loss. Resistance restricts the movement of the bacteria in the plant. Grow varieties that are resistant to the disease. Use insecticides to control flea beetles, particularly on susceptible varieties in the seedling stage. This is not as effective as resistant varieties, but reduces losses where susceptible hybrids must be planted. Scout frequently for flea beetles as rapid growth of leaf tissue makes untreated surfaces available.

■ Maize Dwarf Mosaic Virus (MDMV)

There are several strains of MDMV which are spread by more than 20 species of aphids. The virus can be seedborne in maize and probably in some annual grasses. The virus is nonpersistent but is retained by the aphid for up to 18 hours. This allows time for the vector to be transported from southern states where MDMV is more prevalent and many weed hosts occur. Johnson grass is an important perennial weed host for MDMV occurring in southern New England and it should be eradicated. Plant resistant or tolerant corn varieties. Golden Gleam, Sundance, Spring Gold, Seneca Star, Early Fortune, Sugar Loaf, Dandy and Capitan have some tolerance. Enforcer, Biguard, Silver Red and Seneca 258 are resistant. MDMV is more likely to be a problem for later plantings. Plant late plantings away from peach trees, overwintering host of the green peach aphid.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Caution: Insecticides should not be applied when bees are active in the field. Avoid products with high bee toxicity during pollen shed. If application of an insecticide is necessary while the crop is blooming, select products with low bee toxicity or with short residual period; apply in the evening after the bees have left the field. See Protecting Honeybees and Native Pollinators in the Insect Management section for more suggestions on how to avoid harmful effects on pollinators.

■ Sprayer Type and Configuration

In sweet corn, the best coverage is achieved with a boom-type sprayer with drop nozzles. The nozzles should be arranged so

that one nozzle is over the row and a double-drop system is used between rows, with the lower nozzle is directed up toward the ear and upper nozzle directed down, to bracket the ear zone. For whorl and pretassel stages, one nozzle over the row or with a single drop nozzle is adequate. Use hollow-cone nozzles at 75 to 100 psi to achieve good penetration, droplet size and coverage. Mist blowers do not provide as effective coverage of the ear zone and may result in poorer coverage in the center of the block because each row of corn acts as a filter. However, on hilly land or for other reasons a mist blower may be the most feasible sprayer option. If a mist blower is used, plant fewer rows per block for later corn when insect pressure is typically higher. Direct some spray over the canopy, so it can settle into the corn from above, as well as through the corn rows. Spray only in very calm conditions. For all sprayers, assess sprayer coverage by clipping water-sensitive cards on ears at the edge and center of the block and on both sides of the plant, then spraying water at the pressure and speed normally used.

■ Armyworm, Fall (*Spodoptera frugiperda*) and Common (*Pseudaletia unipunctata*)

The fall armyworm (FAW) does not overwinter in New England. Infestations result from moths carried northward on storm fronts from mid-July into September. Flights are heavier near the coast, but occur inland as well. FAW flights are sporadic and unpredictable, and do not necessarily correspond with corn earworm flights, so monitoring with pheromone traps in whorl stage corn is very useful. Male adult moths are 3/4" long and have mottled brown forewings with a slanting white bar across the wing, and plain light tan hindwings. Female moths lay clusters of eggs on the leaves of a variety of host plants, preferring whorl stage corn to older corn. Eggs hatch in 2 to 10 days, depending upon temperature. Caterpillars are smooth (unlike CEW) and dark green or brown with lengthwise stripes and dark spots. Full-grown larvae reach 1.5 inch. The head capsule is dark with a distinctive light-colored marking in the form of an upside-down Y.

Feeding damage from caterpillars occurs first in whorl stage corn, deep within the whorl, on leaves and in the newly forming green tassel. In whorl stage corn, caterpillars produce ragged feeding damage to leaves and masses of sawdust-like excrement. As corn matures, larvae burrow into the side of corn ears, leaving behind frass and a large hole, and into the tip, making a mess of the kernels and rendering the ear unmarketable. When full grown, larvae drop to the ground and pupate in the soil. The most effective way to prevent ear damage is to apply controls during whorl and tassel stage. If flights remain high throughout ear development, silk sprays may be needed.

Monitor fall armyworm moth flight with a bucket trap (e.g., Universal Moth Trap or Multipher traps) with a lure clipped under the lid (Scentry 4-component lure is recommended) and a vapor strip placed inside the trap. Hang the trap on a stake at plant height in whorl stage corn. Identify and count FAW moths at least weekly. Flag the location well and move the trap to younger corn at tasseling. Replace the lure every 2 to 4 weeks, and the vapor strip every 6 to 8 weeks.

Scout whorl and emerging tassel stage corn by checking 100 plants in groups of 10 or 20 in a V or X pattern across the field. Avoid checking only field edges and select plants at

random, not only where you can see damage. A plant is 'infested' if at least one caterpillar is found. If feeding damage is old and no larva is found, the caterpillar may have left the plant to pupate in the soil. If 15% or more of plants are infested with FAW, a control is needed.

In emerging tassels, combine counts for ECB and FAW. For example, if 10% of plants have FAW and 12% have ECB, the combined infestation is 22%, above the 15% threshold.

Common armyworm, also known as armyworm or true armyworm, migrates from southern areas anytime from March to September. Eggs are laid on grasses and grains in preference to corn and other crops. Larvae feed at night and are grayish green with a broad stripe on each side and a yellow-brown head. Damage is similar to fall armyworm and is often spotty and not sufficient to require treatment. Outbreaks are not common in New England but do occur occasionally, and can cause significant damage.

alpha-cypermethrin (Fastac* EC): 2.8 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OG}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Use alone to control light populations or first and second instar larvae. Add a contact insecticide to control more mature larvae and higher populations. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

Bacillus thuringiensis kurstaki (Dipel DF^{OG}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Use alone to control light populations or first and second instar larvae. Add a contact insecticide to control more mature larvae and higher populations. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. For first and second instar only.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. For fall armyworm. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. For foliar applications.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

chlorpyrifos (Lorsban* 4E): 1 to pint/A; PHI 21d, REI 24h, Bee: H, Group 1B. In reduced tillage system, apply preplant, at-plant or pre-emergence as a broadcast spray. In conventional tillage system, apply postemergence in a minimum of 15 gal/A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Apply to early instar larvae prior to boring into ear or stalk.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. For fall armyworm, target first and second instar only. Direct the application to the ear zone to obtain thorough coverage of the corn silk.

flubendiamide (Belt SC): 2 to 3 oz/A; PHI 1d, REI 12h, Bee: L, Group 28.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. FAW only.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h for mechanically harvested and 14 days for hand harvested, Bee: H, Group 22. Whorl through tassel emergence (prior to silking) application only. For fall armyworm only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Use high rate for large larvae.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d, REI 48h, Bee: H, Group 1A. Some sweet corn varieties may be damaged by methomyl. More severe damage may occur with the Lannate* LV formulation than with the Lannate* SP (Soluble Powder) formulation.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

spinetoram (Radiant SC): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as directed spray into leaf whorls or as broadcast spray.

spinosad (Entrust SC^{OG}): 1.5 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as directed spray into leaf whorls or as broadcast spray.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

■ Brown Marmorated Stink Bug (*Halyomorpha halys*)

See stink bugs in the insect control section of Tomato, Outdoor for information on brown marmorated stink bug.

bifenthrin (Brigade* 2EC): 6.4 oz/A; PHI 1d, REI 12 hr, Bee: H, Group 3A. Do not make aerial or ground applications to corn if heavy rainfall is imminent.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

methomyl (Lannate* LV): 1.5 pt/A; PHI 0d, REI 48h, Bee: H, Group 1A.

■ Corn Earworm (*Helicoverpa zea*)

Corn earworm (CEW) moths migrate annually into the Northeast, traveling north on storm fronts, and may arrive anytime from late June through September. Heaviest numbers are found in coastal areas and up the major river valleys. The severity of infestations varies from year to year and may change suddenly during the season. CEW feeds in a wide range of crops and among vegetables its favorite crops are corn and tomato (hence it is also known as 'tomato fruitworm').

Adult moths are light tan with a distinctive dark spot on each forewing, and a dark band near the margin of the hind wing, and a wingspan of 1.2" to 1.5". Live moths have bright green eyes. Moths are active at night. Fresh silk is highly attractive for egg-laying. When migratory flights arrive, females are ready to lay eggs. Single, globe-shaped eggs are laid directly on fresh silk and hatch in 2.5 to 6 days depending on temperature. Newly-hatched caterpillars crawl down the silk channel and feed on the kernels at the tip, leaving unsightly frass. In the tip, they are protected from insecticide sprays. Corn earworm larvae may be brown, tan, green, or pink, with light and dark longitudinal stripes and reach 1.5 to 2" when full grown. CEW can be distinguished from FAW and ECB by the plain, golden brown head capsule and small bumps and spines that give the body a rough texture.

Monitoring moth flight with pheromone traps is key to successful season-long control, because it enables farms to respond quickly to changes in flight and to avoid unnecessary sprays. Reports of moth trap captures at selected locations are provided in most New England states. The most accurate and timely flight information will be obtained by monitoring your own fields. *Heliothis* net traps baited with Hercon *Heliothis zea* pheromone lures are commercially available and widely used in the region. Place traps in blocks with fresh silk and count moths twice weekly to monitor average nightly catch. Replace lures every 2 weeks and move traps to a block with fresh silk as soon as silk dries.

Sprays or other control measures must be timed to prevent larvae from entering the ear. Control depends upon maintaining insecticide coverage on the silks when eggs are being laid and hatching. Directed sprays to the ear zone provide the best control. Repeat applications to silk every 3 to 6 days depending on trap captures according to the chart below. If maximum daily temperature is below 85°F for 2 to 3 days, spray intervals may be extended by 1 day. Continue treatments until 5 to 7 days before final harvest or until silk is completely dry and brown. Use selective materials to conserve natural enemies of aphids and other pests.

Spray Intervals for Corn Earworm Based on moth captures in <i>Heliothis</i> net traps		
Moths/Night	Moths/Week	Spray Interval
0 - 0.2	0 - 1.4	no spray
0.2 - 0.5	1.4 - 3.5	6 days
0.5 - 1	3.5 - 7	5 days
1 - 13	7 - 91	4 days
Over 13	Over 91	3 days

Bt hybrids that express the insect toxin found in *Bacillus thuringiensis* (*Bt*) in leaves, husks and kernels offer protection against CEW and may not require additional insecticide applications for control of this pest.

alpha-cypermethrin (Fastac* EC): 2.8 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Use alone to control light populations and add a contact insecticide to control moderate to heavy populations. Maintain frequent spray intervals.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. For foliar applications.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Apply to early instar larvae prior to boring into ear or stalk.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h for mechanically harvested and 14 days for hand harvested, Bee: H, Group 22. Whorl through tassel emergence (prior to silking) application only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d, REI 48h, Bee: H, Group A. Some corn varieties may be damaged by methomyl. More severe damage may occur with the Lannate* LV formulation than with the Lannate* SP (Soluble Powder) formulation. May not provide effective control under high corn earworm pressure.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

soybean oil (Golden Pest Spray Oil^{OG}): 0.5 ml applied by hand directly to silk within 6 to 7 days after 50% of the ears are silking; REI 4h, Bee: L, Group 25. Apply at least 5 days after silk initiation to avoid tip injury, and before 7 days after silk initiation to gain optimum control. Mix with *Bacillus thuringiensis*, spinosad or neem for improved control. One application per field. Commercial oil applicators (i.e., Zea-later) are available.

spinetoram (Radiant SC): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as broadcast or directed spray into ear zone.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as directed spray to ear zone or as broadcast spray; ensure thorough wetting of silks. Effective for low to moderate CEW pressure; may be less effective when CEW pressure is high (13 or more moths/night in pheromone trap) or when a 3-day spray schedule is warranted. A 1 to 2-day re-treatment schedule may be necessary at silking.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

■ Corn Leaf Aphid (*Rhopalosiphum maidis*)

The corn leaf aphid (CLA) is blue-green or black, with black legs. These aphids overwinter as eggs or females on grass weeds and grains, including barley and wheat. When these cereals mature, winged aphids develop and migrate to corn and wild grasses. Both winged and wingless female aphids occur together. Females produce live young (nymphs) which mature in as little as 6 days, resulting in many generations per year. In corn, CLA first colonize whorl leaves and the immature tassel. Populations may become numerous enough to interfere with pollen shed and to stunt plants, and to infest layers of the husk with aphids. Maize dwarf mosaic virus may be spread by the corn leaf aphid, though the most important vector for this disease is the green peach aphid. In addition, aphids excrete a sugary liquid called 'honeydew' which coats leaves and husks and encourage growth of sooty mold fungus. The presence of aphids and honeydew on corn husks reduces their marketability. Varieties with purple or green tassels seem to be less susceptible to aphid build-up than those with yellow tassels. Ample rainfall or irrigation during the silk stage can reduce or eliminate aphid damage. Natural enemies reduce aphid numbers, but may not provide adequate control, especially in dry seasons. Whenever possible, conserve predators and parasites by using selective insecticides to control caterpillars. Sweet corn plantings that are seeded before 10 June are generally not bothered by corn leaf aphids. Monitor for aphids while scouting whorl or pre-tassel stage corn for ECB or FAW in July and August. Pre-tassel stage sprays may be needed when 50% of the plants are infested, or if 25% have heavy infestations. Sprays applied before 50% of the tassels emerge are more effective than later sprays.

alpha-cypermethrin (Fastac EC*): 2.8 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Suppression only.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

flupyradifurone (Sivanto): 7 to 14 fl oz/A; PHI 7d, REI 4h, Bee: M, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Suppression only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Suppression only.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d for ears, PHI 3d if used for forage, REI 48h, Bee: H, Group 1A. See ECB section for phytotoxicity warning.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L.

thiamethoxam (Cruiser 5FS): 1.28 to 5.1 oz/100 lb of seed; REI 12h, Bee: H, Group 4. Systemic seed treatment. Use standard slurry seed treatment equipment to ensure uniform coverage of kernels. For early season protection from corn leaf aphid.

■ Cutworms, including Black Cutworm (*Agrotis ipsilon*)

Black cutworm is the most common of the many cutworm species that damage corn in New England. Adults are night-flying tan and black moths, while the caterpillars are dark-grey to black and up to 2" in length. Moths from the South arrive between March and June. Eggs are laid mostly on grasses and winter annual weeds, usually near areas of the field prone to flooding. Certain fields tend to have a history of repeated cutworm damage. The larvae feed after dark while hiding under the soil surface during the day. There are 2 to 3 generations per year but usually only the first generation, which produces larvae in May and June, damages corn. Small larvae feed on leaves and occasionally larger larvae cut seedlings off near the soil line. Adults can be monitored with a yellow and white Unitrap from March through May. A catch of over 40 moths before June indicates that frequent spring and early summer scouting is prudent. Scout problem fields weekly, checking at least 100 plants for leaf feeding and cut stems, especially near field margins. Spot spray heavily hit areas or edges of the field if 5% of the plants have been cut down. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Foliar-applied rescue treatments are recommended over preventative soil-applied insecticides. Ground beetles, parasitic flies and wasps and other general predators help reduce populations. When corn follows sod/hay in rotation, fall-plowing may lower cutworm populations by reducing spring egg-laying sites. Weedy and reduced-till fields tend to suffer the most damage.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin + tebuprimphos (Aztec* 2.1G): 6.7 oz/1000 row ft; REI 48h, Bee: H, Groups 3A and 1B.

bifenthrin (Capture* LFR): 3.4 to 13.6 oz/A for at-plant applications; 4 to 5.3 oz/A for pre-plant incorporation applications; 3.4 oz/A for pre-emergence applications; REI 12h, Bee: H, Group 3A. Apply as T-band over open furrow or over the row on soil surface, in-furrow with the seed, or incorporated pre-planting to seed planting depth.

carbaryl (10% Sevin Granules): 10 lb/A; PHI 2d, REI 12h or 21 days for workers detasseling corn, Bee: H, Group 1A. Ground broadcast equipment applications only. Hand harvesting prohibited.

chlorpyrifos (Lorsban* 4E): 1 to 2 pint/A; PHI 21d, REI 24h, Bee: H, Group 1B. In reduced tillage system, apply as broadcast spray to surface preplant, at-plant or preemergence. In conventional tillage, apply postemergence to moist soil at night when cutworms are active, with shallow incorporation.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

deltamethrin (Delta Gold*): 1 to 1.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Apply to early instar larvae prior to boring into ear or stalk.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

ethoprop (Mocap* 15%G): 20 lb/A; REI 48h, Bee: H, Group 1B. Apply 3 days before planting toat-planting time. Broadcast and incorporate immediately into top 2" of soil.

gamma-cyhalothrin (Declare*): 0.041 oz/1000 row ft for at-plant soil application, 1.02 to 1.54 oz/A foliar; PHI 1d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.33 fl oz/1,000 ft. as T-band or furrow application at planting, 1.28 to 1.92 oz/A foliar; PHI 1d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* SP): 0.5 lb/A; PHI 0d, REI 48h, Bee: H, Group 1A. Some sweet corn varieties may be damaged by methomyl. More severe damage may occur with the Lannate* LV formulation than with the Lannate* SP (Soluble Powder) formulation.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 1d, REI 4 h, Bee: M, Group 5. Spread bait on soil around plants; reapply after heavy rain or at least every 2 to 4 weeks but not more than 3 times per 30 days.

tefluthrin (Force* CS): 0.46 to 0.57 oz/1000 row feet; REI 48h, Bee: H, Group 3A. For t-banded or in-furrow applications.

thiamethoxam (Cruiser 5FS): 1.28 to 5.1 oz/100 lb of seed; REI 12h, Bee: H, Group 4A. Systemic seed treatment. Use standard slurry seed treatment equipment to ensure uniform coverage of kernels. For early season protection from black cutworm.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

■ European Corn Borer (*Ostrinia nubilalis*)

European corn borer (ECB) is a resident pest that has 2 generations per year in southern and central New England and 1 generation in northern New England. Sweet corn is one of over 200 crop and weed host plants of this pest; other vegetable crops affected include bean, pepper and potato. Larvae overwinter in stalks of corn and other host plants and pupate in the spring. Adult moths emerge in late May or early June and mate in weedy or grassy areas. Growing degree days (GDD) with a base temperature of 50°F may be used to predict the beginning of moth flight (374 GDD), first eggs (450 GDD), and peak flight (631 GDD). The moths are about ¾" long, light brown in color with lighter bands on the wings. Three to 7 days after emergence, depending on temperature, females begin to lay flat, white egg masses on the underside of leaves in early corn. Eggs hatch in about 5 to 7 days (100 degree days). ECB larvae are light-colored, with a pattern of small dark spots on each segment. The head capsule is flattened and black or dark brown. Newly hatched larvae are 1/8" long and full-grown larvae are 3/4" to 1" long. Larvae feed in the whorl, leaving pinhole damage, and in the succulent emerging tassel creating brown frass in the florets. As the corn matures, these larvae move downward, bore into the stalk and tunnel into ears through the side or tip. Pupae form inside larval tunnels in the stalk. A second flight begins in mid-July to mid-August, depending on location and the seasonal growing degree day accumulation (beginning of second flight, 1400 GDD; first eggs 1450 GDD; egg hatch 1550 GDD). When moths are

active during silking, eggs are laid on leaves near the ear and larvae move directly into the ear by tunneling through the husk or down the silk channel.

Since the ECB overwinters as a mature larva in corn stalks and stubble, plowing under corn refuse in the fall or early spring will help control this pest. Fields that have been in sweet corn or field corn for a long time tend to have higher pressure from ECB. Weedy fields also have higher pressure. Natural enemies include the twelve-spotted ladybeetle which preys on eggs and small larvae. Releases of *Trichogramma ostrinae*, a tiny parasitic wasp which attacks ECB eggs, can reduce the need for insecticide applications. See Table 22, [Biological Controls for Insect Pests for more information](#).

ECB flight can be monitored with 2 Scentry Heliothis net traps baited with either a New York E (II) or Iowa Z (I) lure, placed at least 50' apart in weedy borders of corn fields with the bottom at weed height. Both types of lures are needed in New England because both E and Z strains are present. Check traps once or twice per week and replace lures every 2 weeks. Once flight is detected, corn with newly emerging tassels should be scouted weekly for the presence of ECB larvae by inspecting the tassels of 50 to 100 plants, in groups of 5 to 20 plants throughout the field. Treat if more than 15% of the plants have one or more larvae present. Timing sprays for tassel emergence reaches larvae in the whorl and the young tassel. A sprayer configuration with one nozzle directed into the tassel and a single drop nozzle to the upper parts of the plant gives the best control. At high levels of infestation, 2 applications may be needed to provide control. Use of selective products to control ECB will conserve natural enemies of aphids and ECB.

Corn started under plastic or row cover often reaches silk stage during the first flight of ECB, such that the first eggs laid hatch during ear development. As a result, ears can be heavily infested by this pest even though scouting in early tassel did not show any feeding damage or larvae. If plants are in silk and moths are active, it is important to protect developing ears. This is also true for late season corn during the second ECB flight, especially when other caterpillar pests are absent.

Genetically modified *Bt* hybrids that express the insect toxin found in *Bacillus thuringiensis* (*Bt*) generally provide adequate defense against European corn borer and may not require additional insecticide applications, but scouting is still recommended to assess ECB and other pests.

alpha-cypermethrin (Fastac* EC): 2.8 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. See the general recommendations for *B.t. kurstaki* below. For resistance management, may be rotated with *Bt kurstaki* products.

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply when larvae are actively feeding. Ensure good coverage and use a spreader sticker. Use a shorter spray interval (4 to 5 days) and high rates under high borer pressure. For resistance management, may be rotated with *Bt aizawai* (XenTari).

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Applications must be made prior to larva boring into the plant.

carbaryl (Sevin XLR Plus): 1.5 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. For foliar applications.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Apply to early instar larvae prior to boring into ear or stalk.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h for mechanically harvested and 14 days for hand harvested, Bee: H, Group 22. Whorl through tassel emergence (prior to silking) application only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Use higher rates for large larvae.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d, REI 48h, Bee: H, Group 1A. Treat a small area of the field to determine cultivar sensitivity before spraying entire field. Phytotoxicity may occur on some varieties. More severe damage may occur with the Lannate* LV formulation than with the Lannate* SP (Soluble Powder) formulation.

methoxyfenozide (Intrepid 2F): 4 to 16 oz/A; PHI 3d, REI 4h, Bee: L, Group 18. Direct application at the whorl for early season infestations; broadcast over row for mid- to late-season infestations.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

spinetoram (Radiant SC): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as directed spray into leaf whorls or as broadcast spray.

spinosad (Entrust SC^{OG}): 1.5 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Apply as directed spray into leaf whorls or as broadcast spray. Time applications to coincide with peak egg hatch of each generation. Frequent treatments may be necessary when the crop is growing rapidly, during silking or under heavy pest pressure.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

■ Flea Beetle, Corn (*Chaetocnema pulicaria*)

Corn flea beetles are black, tinged with bronze or bluish green, and overwinter in plant residue around the fields. They move to corn seedlings in early spring, where they feed

and lay eggs in soil. Direct feeding damage is not significant, but economic damage can be caused by Stewart's bacterial wilt, which is vectored by the beetles. Cold winters reduce the risk of this disease, while mild winters improve beetle survival and hence transmission of wilt. A Winter Temperature Index uses the sum of the average monthly temperatures of December, January and February (in °F) to forecast the Stewart's wilt severity for the season: wilt is predicted to be absent if the Index is <90°F, intermediate if 90°F to 100°F, and destructive if >100°F. The disease may appear on the earliest plantings and grow worse on succession plantings of susceptible varieties. Use resistant or tolerant varieties where possible, especially on early plantings (see Sweet Corn Varieties Section). Spunbonded row covers protect plants against this pest. Scout on sunny, calm days when beetles are active. Start applications when plants are in the spike stage if beetles are present and causing damage, especially on susceptible varieties. Apply additional treatments as needed.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies.

chlorpyrifos (Lorsban* 4E): 1 to 2 pint/A; PHI 21d, REI 24h, Bee: H, Group 1B. Apply in 9" to 12" wide band over the row before corn is 6" tall or if more than 6", direct spray to base of plant.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

deltamethrin (Delta Gold*): 1 to 1.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d, REI 48h, Bee: H, Group 1A. See ECB section for phytotoxicity warning.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

phorate (Thimet* 20-G): 4.5 to 6 oz/1,000 row feet; PHI 30d, REI 48h, Bee: H, Group 1B. Apply in a 7" band over the row at planting and lightly incorporate. DO NOT use in-furrow.

terbufos (Counter* 20G): 4.5 to 6 oz/1,000 row feet for any row spacing; REI 48h, Bee: M, Group 1B. Place granules in seed furrow behind planter shoe or in a 4-5" band over the row, and lightly incorporate.

thiamethoxam (Cruiser 5FS): 1.28 to 5.1 oz/100 lb of seed; REI 12h, Bee: H, Group 4A. Systemic seed treatment. Use

standard slurry seed treatment equipment to ensure uniform coverage of kernels. For early season protection from corn flea beetles.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

■ Japanese Beetle (*Popillia japonica*)

These beetles feed on corn silk, but are usually controlled by sprays directed at controlling ECB and corn earworm.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Adults only.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Adults only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Adults only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Adults only.

pyrethrin (PyGanic EC5.0^{0G}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Adults only.

■ Sap Beetles, Fourspotted (*Glischrochilus quadrisignatus*) and Dusky (*Carpophilus lugubris*) Sap Beetle

Sap beetle problems are more likely to occur on farms producing a variety of fruit and vegetable crops. Adult beetles are 3/16" long and are black (Dusky sap beetle), or black with orange spots (Fourspotted sap beetle, also known as 'picnic beetle'). They survive the winter as pupae or adult beetles under soil or plant debris in fields, or under leaf litter along hedgerows and field margins. Eggs may be deposited in rotting fruit or discarded vegetable debris (cull piles), in wounds created by corn borer or birds, and on silk or in kernels at the tip of the ear. Eggs are milky white and resemble tiny grains of rice, about 1/16" long. The larva is a white or light yellow grub that resembles a tiny, thin caterpillar or maggot. Larvae hollow out developing kernels, and damage may be found in the tip and scattered through the upper half of the ear. Full grown larvae drop to the ground to pupate in the soil. Marketability of ears declines when damage, larvae or adults are present on or in kernels. Adults feed on pollen, sap, silk and injured or rotting fruit. Males have an aggregation pheromone that attracts other beetles, both male and female. Adults move to corn at full tassel to feed on pollen, and build up as corn matures and silk turns brown. There are 2 to 4 generations per year with peak infestations in July (larvae) and late July and August (adults).

Cultural controls are essential to managing sap beetles. Ears with exposed tips, especially super sweet and *Bt* varieties, are more susceptible to infestation. Research has shown that both the length and tightness of the tip cover is important to reduce infestations. Some varieties with long, tight tip cover include: Accord, Argent, Avalon, Awesome, Bon Jour, Cuppa-Joe, Easy Money, Fantasia, Ka-Ching, Precious Gem, Prime Plus, Profit, Providence and Renaissance. To prevent or reduce damage, select varieties that have good tip cover, use clean cultivation, and control birds and ear-infesting caterpillars. Eliminate or bury deeply any cull piles or other areas with decaying vegetables or fruit, included infested ears. Do not leave infested blocks standing; mow aggressively to chop ears as soon as the block is finished. Deep plowing may be necessary after harvest if infestations are high, to bury ears at least 4" deep.

Scout blocks at full tassel and early silk to determine if beetles are present. Unfortunately, there are no specific thresholds based on scouting. Insecticides may be warranted in fields with a previous history of 10% ear damage. Research in Maryland showed that ear infestation begins just after silk emerges and that 1 or 2 applications made 3 and 6 to 7 days after silking begins is more effective than later or more applications. Insecticides will reduce the number of damaged kernels and ears but will not completely control heavy infestations. Sap beetle adults and larvae are not susceptible to the *Bt* toxin that is present in *Bt* corn. Efficacy trials have shown that carbaryl (Sevin), lambda-cyhalothrin (Warrior II), bifenthrin (Bifenture), and methomyl (Lannate) are more effective than most other insecticides. However, carbaryl cannot be used during the early silk period while corn is shedding pollen and does not allow for hand harvesting after use.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 2d, REI 12h, Group 1A. 1 to 2 qt/A; PHI 2d ears, REI 24h or 21 days for workers detasseling corn, Bee: H, Group 1A. Hand harvesting is prohibited. Highly toxic to bees; avoid use in corn that is shedding pollen. May encourage buildup of aphids by killing natural enemies. Sap beetles only.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Adult sap beetle only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Adult sap beetle only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Adult sap beetle only.

malathion (Malathion 57 EC): 1.5 pt/A; PHI 5d, REI 12h or 72h for workers detasseling corn, Bee: H, Group 1B. Begin treatment when 10% of ears show silk. Apply when nymphs are young. Injury may occur in the whorl and silk stages using this type of Malathion product.

methomyl (Lannate* SP): 0.25 to 0.5 lb/A; PHI 0d for ears, PHI 3d if used for forage, REI 48h, Bee: H, Group 1A. See ECB section for phytotoxicity warning.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Adult sap beetle only.

■ Seedcorn Maggot (*Delia platura*)

See seedcorn maggot in the insect control section of Beans for more information about biology and management.

beta-cyfluthrin + tebuprimphos (Aztec* 2.1G): 6.7 oz/1000 row ft; *REI 48h, Bee: H, Groups 3A and 1B.*

bifenthrin (Capture* LFR): 3.4 to 6.8 oz/A for at-plant applications; 4 to 5.3 oz/A for pre-plant incorporation applications; *PHI 2d, REI 12h, Bee: H, Group 3A.* Apply as T-band over open furrow, in-furrow with the seed, or incorporated pre-planting to seed planting depth.

chlorpyrifos (Lorsban* 15G): 8 oz/1,000 linear ft of row; *PHI 21d, REI 24h, Bee: H, Group 1B.* Use as a T-band or in-furrow treatment at planting.

gamma-cyhalothrin (Declare*): 0.041 oz/1000 row ft for at-plant soil application; *PHI 1d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 0.33 fl oz/1,000 ft as T-band or furrow application at planting; *PHI 1d, REI 24h, Bee: H, Group 3A.*

phorate (Thimet* 20-G): 4.5 to 6 oz/1,000 row feet in a 7" band over the row at planting and lightly incorporate; *PHI 30d, REI 48h, Bee: H, Group 1B.* DO NOT use in-furrow.

tefluthrin (Force* CS): 0.46 to 0.57 oz/1000 row feet; *REI 48h, Bee: H, Group 3A.* For t-banded or in-furrow applications.

terbufos (Counter* 20G): 4.5 to 6 oz/1,000 row feet; *REI 48h, Bee: M, Group 1B.* Place granules in seed furrow behind planter shoe or in a 4-5" band over the row, and lightly incorporate.

thiamethoxam (Cruiser 5FS): 1.28 to 5.1 fl oz/100 lb of seed; *REI 12h, Bee: H, Group 4A.* Systemic seed treatment. Use standard slurry seed treatment equipment to ensure uniform coverage of kernels. For early-season protection from seedcorn maggot.

■ Stalk Borer (*Papaipema nebris*)

Stalk borer (also known as common stalk borer) is an occasional pest of corn and of other vegetable crops. It is the egg stage that overwinters, on grassy weeds where adult moths deposited them in the fall. Upon hatching in the spring, the caterpillars feed on grasses by boring into and along the stalk. When the caterpillars become too large to feed within the grass, they migrate to nearby thicker-stemmed wild and cultivated plants. In corn, infestations are heaviest in border rows and in fields with grassy weeds. Borers feed in the stalk or deep in the whorl, which may kill the growing tip. Larvae are brown to purplish brown with a broad white stripe on the back and each side. These stripes are interrupted by a distinctive, large brown spot around the whole body. Pupation occurs in the soil in late summer, with adult emergence and activity from August to October. There is one generation per year. Reduced tillage fields, which may have higher levels of grassy and broad-leaf weeds, may result in increased levels of stalk borer. To reduce overwintering eggs, prevent or eliminate grassy weeds especially from August on. Destroy weeds and grasses at field margins to reduce invasions at field borders. Scout for injury soon after the corn emerges in the spring and treat infested corn as needed. Apply insecticides to outer rows at the first sign of damage by this pest. Treat small larvae before they bore into stalks.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.* Application must be made prior to larva boring into the plant.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; *PHI 1d, REI 24h, Bee: H, Groups 28 & 3A.*

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo[®]):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Apply to early instar larvae prior to boring into ear or stalk.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.*

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Wireworms and White Grub

See wireworms in the insect control section of Potato for more information. To avoid wireworm problems, corn should not be grown in rotation with sod or grass crops. Delay planting susceptible crops, such as corn or potatoes, on such land for at least two years after the sod has been broken. Summer fallow is recommended for at least one season.

Land that was in sod or pasture should be planted to legumes, such as alfalfa or clover, for a year or more before planting corn or other vegetables to reduce the number of white grubs in the soil. Plow or harrow in mid-summer, after harvesting early corn, to reduce grub numbers.

beta-cyfluthrin + tebuprimphos (Aztec* 2.1G): 6.7 oz/1000 row ft; *REI 48h, Bee: H, Groups 3A and 1B.*

bifenthrin (Capture* LFR): 3.4 to 13.6 oz/A for at-plant applications; 4 to 5.3 oz/A for pre-plant incorporation applications; *PHI 2d, REI 12h, Bee: H, Group 3A.* Apply as T-band over open furrow, in-furrow with the seed, or incorporated pre-planting to seed planting depth.

chlorpyrifos (Lorsban 15G): 8 oz/1,000 linear ft of row; *PHI 21d, REI 24h, Bee: H, Group 1B.* Apply as a T-band or in-furrow treatment at planting. For best control of wireworms, apply as an in-furrow treatment.

ethoprop (Mocap* 15%G): 8 oz/1,000 row feet; *REI 48h, Bee: H, Group 1B.* Apply as 6" to 7" band over closed seed furrow, then incorporate immediately into top 0.5" of soil. Suppression only for white grubs. Extremely toxic to birds; do not leave granules on soil surface.

gamma-cyhalothrin (Declare*): 0.021 oz/1000 row ft for at-plant soil applications; *PHI 1d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 0.33 fl oz/1,000 ft. as T-band or furrow application at planting; *PHI 1d, REI 24h, Bee: H, Group 3A.*

phorate (Thimet* 20-G): 4.5 to 6 oz/1,000 row feet; *PHI 30d, REI 48h, Bee: H, Group 1B.* Apply in a 7" band over the row at planting and lightly incorporate. DO NOT use in-furrow.

tefluthrin (Force* CS): 0.46 to 0.57 oz/1000 row feet; *REI 48h, Bee: H, Group 3A*. For T-banded or in-furrow applications. Use high rate for heavy infestations. For best control, place in seed furrow.

terbufos (Counter* 20G): 4.5 to 6 oz/1,000 row feet; *REI 48h, Bee: M, Group 1B*. Place granules in seed furrow behind planter shoe or in a 4-5" band over the row, and lightly incorporate.

thiamethoxam (Cruiser 5FS): 1.28 to 5.1 fl oz/100 lb of seed; *REI 12h, Bee: H, Group 4A*. Systemic seed treatment. Use standard slurry seed treatment equipment to ensure uniform coverage of kernels. For early-season protection from wireworms and white grub (including Japanese beetle larvae, European chafer larvae, true white grub, annual white grub, May/June beetle larvae).

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

Delayed Herbicide Applications

Growers using atrazine (Aatrex) and/or mesotrione (Callisto) for broadleaf weed control and either metolachlor (Dual) or pyroxasulfone (Zidua) for grass control in corn should consider delayed applications in their earliest plantings. Reasons for delaying herbicide applications in the earliest sweet corn plantings include:

1. Corn is most tolerant to both Dual and Zidua after emergence. Supersweet varieties and some "se" sweet corns are easily injured by these herbicides when the soil is below 60°F. Both Dual and Zidua as well as atrazine and Callisto can be applied at any time as long as the corn is less than 5" high. Bicep Lite II, a very commonly used prepack of atrazine and Dual, can also be used this way as can Lumax, a prepack of metolachlor, atrazine, and mesotrione.
2. If the first few plantings of sweet corn are sprayed on the same day, the amount of cleaning and rinsing of the spray tank is reduced since it does not need to be cleaned between applications when the same herbicide is used.
3. Delaying herbicide applications on the earliest plantings will also extend the activity of the herbicide later into the season. This is important in maintaining good weed control throughout the season to minimize weed seed production. Growers often rely on sweet corn rotations to reduce weed seed populations in the soil.

Growers should consider waiting until their first planting of sweet corn is 3" to 5" high to apply herbicide. At this time all fields of sweet corn planted to date can be treated. Each field sprayed will be at a different stage of growth. After that, each field should be sprayed soon after it is planted, since soils will be warmer and grasses are more likely to emerge soon after seeding the crop.

A possible problem with delayed applications involves the potential for poor control of grasses. Dual, Zidua, Bicep

(atrazine + Dual), or Lumax (atrazine + Dual + Callisto) must be applied before grasses emerge. If grasses are not controlled in corn, yield reductions will likely occur. Also, as the soil warms up, grasses are likely to emerge soon after seeding.

Reduced Herbicide Rates for Corn Weed Management

Be sure to follow the herbicide rates recommended in this guide. Only 1 lb active ingredient of atrazine is recommended for sweet corn in New England. This is well below the rate on the label and constitutes best management practices for groundwater protection. This rate could be reduced further, although the grower should be prepared to make a second application of atrazine if any weeds escape. Rates for Dual and Lasso should be selected based on soil type. Follow the label to determine the correct rate. Reducing the rate of Dual or Zidua is risky since it is very difficult to control grasses in sweet corn once they emerge.

Special Atrazine Precautions

The Environmental Protection Agency and Syngenta have revised the label uses of all atrazine products to reflect the potential for surface and groundwater contamination. Be sure to read and follow all directions and restrictions listed on the label. The preceding section on Reduced Herbicide Rates for Corn Weed Management reflects these concerns. All of the rates listed in this guide for atrazine are within the guidelines of the label. These include uses for single applications (applied before crop emergence or early postemergence) and sequential applications (applied both at planting and postemergence). Please read all labels carefully.

■ Stale Seedbed Applications

The following herbicides are nonselective and are used to control weeds which are present in a field prior to planting the sweet corn or before the sweet corn emerges (see Stale Seedbed Technique, page 107. If a grower is using "no-till" or "minimum tillage," these herbicides are also used to kill the cover crop that may be present in the field.

glyphosate (Roundup Power Max): *REI 12h, Group 9*.

Apply to emerged annual or perennial weeds prior to crop emergence. Do not feed crop residue to livestock for 8 weeks following treatment. Consult the manufacturer's label for specific weeds and rates. May be tank mixed with atrazine, simazine or alachlor.

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22*. Use 2-4 pts/A. Apply in 20 to 60 gallons spray mix to emerged weeds. Field should be prepared several days ahead of treatment to allow maximum weed emergence. Use a nonionic surfactant at a rate of 16 to 32 oz per 100 gal spray mix. May be tank mixed with atrazine or simazine preemergence. Can also be applied as a preemergence. Check label for directions.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17*. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

acetochlor (Surpass): *REI 12h, Group 15*. Not for use in New Hampshire. Works to inhibit weed seed germination, and will not work on emerged weeds. Labeled for control of annual grasses and broadleaf weeds. Can be used early

preplant, preplant incorporated, preemergence, postplant-preemergence, and early crop postemergence. Rates based on both soil texture and tillage system used (conventional, reduced, or no-till). Read label for proper rate selection. Also see label for herbicides approved as tank-mixing partners.

dimethenamid (Outlook): *PHI 50d, REI 12h, Group 15.* May be applied preplant surface, preplant incorporated, preemergence, or postemergence to corn up to 12-inches tall. May be applied in a single application or two split applications. When used as a single application, apply as a single application (12 to 18 oz/A on coarse-textured soil and 14 to 21 oz/A on finer textured soils. See label for specific maximum application rates of depending on soil type and organic matter content. A split application may be used (10 to 14 oz/A per application, not to exceed 21 oz/A total). Allow a minimum of 14 days between applications. Do not exceed a seasonal total of 24 fl ozs/A. If two applications are made, apply no more than 8 to 16 oz/A during the first application (applied preplant, preemergence, or postemergence), then apply the remainder (8 to 16 oz/A) of the seasonal maximum rate during the second application (postemergence). Can be tank mixed with many other herbicides, see label for details. Check with seed supplier for potential varietal susceptibility to injury. Outlook is a selective residual herbicide for controlling many annual grasses, annual broadleaf weeds, and sedges as they germinate. Will not control emerged weeds.

pendimethalin (Prowl H₂O): *REI 24h, Group 3.* Apply before weed germination. Emerged weeds will not be controlled. Work against annual grasses and some broadleaf weeds. Can be used after planting but before weeds germinate and crop emerges, or after corn emerges until it is 20 to 24-inches tall or at V8. Rate based on soil texture, see label for details. When used after planting, there is potential for crop injury if herbicide is moved into the seed zone. Minimize the potential for crop injury by preparing a firm seedbed and planting corn seed at least 1.5" deep. If heavy rains follow an application to dry soil, Prowl can move to the seed zone and cause crop injury. Specific weeds for which this herbicide should be considered include triazine-resistant lambsquarters, and velvetleaf.

pyroxasulfone (Zidua): *PHI 37d, REI 12h, Group 15.* A root-and-shoot growth inhibitor that controls susceptible germinating seedlings before or soon after they emerge from the soil. Application rates vary depending on soil texture, see label for details. May be applied preplant surface, pre-plant incorporated, preemergence, or early postemergence to corn for residual preemergence control of weeds. See label for application instructions for each timing. Plant corn seed at least 1" deep. Labeled for use against many annual grasses and broadleaf weeds. Controls most annual grasses including crabgrass, panicum, foxtails, and barnyardgrass. Weak on common lambsquarters but will control redroot pigweed, carpetweed, nightshade, and common purslane. Has activity on yellow nutsedge.

s-metolachlor (Dual Magnum): *PHI 30d, REI 12h, Group 15.* Can be used either preplant surface, preplant incorporated, preemergence, or lay-by. See label for application instructions and rates based on timing and soil type.

simazine (Princep): *PHI 45d, REI 12h, Group 5.* Apply up to 2 qt/A preplant incorporated or to the soil surface immediately after planting before corn emerges. Use alone only if annual grasses are not a problem. Do not apply on highly erodible soils unless there is at least 30% plant residue cover.

■ Herbicides Used Pre- and Postemergence to Weeds

2,4-D (Amine 4): *PHI 45d, REI 28h, Group 4.* Can make one preplant or preemergence application per crop cycle. Apply up to 2.14 pt/A (1.0 lb ae/acre) to soil anytime after planting but before corn emerges. Can make one postemergence application per crop cycle. Apply a maximum of 1.07 pt/A (0.5 lb ae/acre) per application. Use drop nozzles to direct spray toward base if corn is over 8" tall. Do not apply from 7 to 10 days before tasseling to dough stage. Allow a minimum of 21 days between applications. Use a maximum of 3.2 pts/acre (1.5 lbs ae/acre) per year. Reduce rate of 2,4-D if temperature is hot and soil is wet. Use only the amine formulation of 2,4-D; Do not use any ester or low-volatile ester formulations. Use all precautions to avoid spray drift to desirable broadleaf crops.

atrazine (Aatrex 4L): *REI 12h, Group 5.* Apply preplant incorporated or to the soil surface immediately after planting. Use alone only if annual grasses are not a problem. Shallow cultivation may help to control annual broadleaf weeds. May be tank mixed with any of the preemergence grass herbicides listed above as well either glyphosate or paraquat for burndown of existing weeds.

For postemergence applications, add either 1 qt/A of crop oil concentrate or 1 gal/A of spray oil. Apply when weeds are 1 to 1 1/2" high and before corn is 12" high. This treatment can be used as the primary broadleaf herbicide treatment instead of an application at planting or it can be used as an emergency treatment if the soil-applied broadleaf herbicide treatment failed. If applied correctly, this application will control the emerged weeds and will continue to provide residual control for later-emerging broadleaf weeds. Check label for additional precautions regarding the use of crop oil and petroleum oils.

Only 1 lb active ingredient of atrazine is recommended for sweet corn in New England. This is well below the rate on the label and constitutes best management practices for groundwater protection. This rate could be reduced further, although the grower should be prepared to make a second application of atrazine if any weeds escape.

halosulfuron (Sandea): *PHI 30d, REI 12h, Group 2.* Apply 2/3 to 1 oz/A over the top or with drop nozzles from the spike through layby stage of the corn. If necessary, a sequential treatment of this product at 2/3 oz/A acre may be applied only with drop nozzles semi-directed or directed to avoid application into the corn plant whorl. Do not apply more than 2 applications per year. Do not use on "Jubilee" sweet corn. Other varieties may also be sensitive to injury. The use of non-ionic surfactant is recommended for use on emerged weeds (1 to 2 qt/100 gal spray). Works on germinating broadleaf weed seeds, and also on emerged broadleaf weeds. Control varies with type and size of weed. Species listed on the label include redroot pigweed, pokeweed, common ragweed, Pennsylvania smartweed, common sunflower, velvetleaf, wild mustard, yellow nutsedge, and wild radish. Do not cultivate for 7 days after application.

mesotrione (Callisto): *PHI 45d, REI 12h, Group 28.* May be applied by ground for preemergence or postemergence weed control. See label for list of susceptible species.

Callisto provides excellent control of many problem broadleaf species such as velvetleaf and triazine-resistant lambsquarters. Callisto provides only partial control of yellow nutsedge and no control of ragweed when applied postemergence.

Make a single preemergence application of 6.0-7.7 oz/A after seeding to the soil surface. Can be tank mixed with many other herbicides, and it also included in some premixed products. See label for details. Use 5 to 6 oz/A if tank mixing with atrazine. In a tank mix, the atrazine rate can be reduced to 0.5 to 1 pt/A. A grass herbicide must also be used. On cool soils in the spring, Callisto may be a better option than using Prowl to control these two weed species. Callisto does not provide preemergence control of yellow nutsedge. With this weed, it is important to continue to use atrazine (alone or in combination with Callisto) as well as either Dual, Outlook, or Zidua preemergence. See the label for precautions and more information on tank mixes, rates, and weeds controlled.

For postemergence weed control, apply 3 oz/A to corn up to 30" tall when weeds are no more than 3" tall. Include a nonionic surfactant. Do not make more than 2 applications per season to corn and do not exceed a total of 7.7 oz/A of Callisto. Applications should be a minimum of 14 days apart. Use other options if these weeds are present. See the label for precautions and more information on tank mixes, rates, and weeds controlled. Severe corn injury resulting in yield loss may occur if any organophosphate or carbamate insecticide is applied foliar postemergence within 7 days before or 7 days after Callisto application. May cause crop bleaching in some yellow popcorn and sweet corn hybrids. Crop bleaching is typically transitory and has no effect on final yield or quality.

■ Herbicides Used Postemergence to Weeds

The following herbicides are applied after weeds have emerged. They can be used as the only broadleaf weed control to supplement a soil-applied grass herbicide or they can be used as an emergency treatment if the soil-applied broadleaf herbicide fails to provide adequate control. Timing is very important when using these herbicides. Be careful to check both the ideal weed stage of growth as well as the ideal timing and application precautions for the crop.

bentazon (Basagran): *PHI 30d, REI 48h, Group 6.* Apply early post-emergence overtop when weeds are small and corn has 1 to 5 leaves. Rate varies based on weed species targeted (1 to 2 pt/A). See label for info. Bentazon will not control redroot pigweed and will provide only partial control of common lambsquarters, giant ragweed and morning glory. Bentazon should be primarily used as an emergency treatment when a soil-applied broadleaf herbicide has failed. There is less chance of adjacent crop injury from spray drift than with 2,4-D.

carfentrazone (Aim EC): *REI 12h, Group 14.* Apply 0.5 to 1 oz/A to actively growing weeds anytime from preplanting until corn is at the 14 leaf-collar stage. Can be broadcast applied until corn reaches the 8 leaf-collar stage. For application after corn is at the 8 leaf-collar stage, use drop

nozzles to avoid spraying into the whorl and on the corn foliage. Tank mix with atrazine at reduced rates or another broadleaf herbicide to increase the spectrum of weeds controlled. Add non-ionic surfactant at a rate of 1 qt/100 gal spray solution. Expect to see speckling of the crop foliage after application. Initially, the injury appears to be substantial, but it is not systemic and the corn outgrows the injury rapidly. Cultivar sensitivity may vary with Aim. Use caution when treating new cultivars. Weather conditions may also affect the degree of injury observed. Injury may be more severe during periods of warm, cloudy weather with high humidity and plentiful soil moisture when corn growth is rapid and soft. Do not apply more than 2 oz/A per season. Works best before weeds reach 4" tall or rosettes are 3" in diameter.

clopyralid (Stinger): *PHI 30d, REI 12h, Group 4.* For postemergence control of weeds in the composite and legume families. Use Stinger for postemergence control of annual sowthistle, Canada thistle, common cocklebur, common sunflower, giant and common ragweed, Jerusalem artichoke, jimsonweed and other broadleaf weeds infesting field corn. Apply timing and rates specified on the label. Spray additives are not needed or required by the label and are not recommended. Stinger is a postemergence herbicide with some soil residual activity. Observe replant restrictions on the label or injury may occur from herbicide carryover.

fluthiacet-methyl (Cadet): *REI 12h, Group 14.* Can be applied as a preplant burndown or after corn emerges as a postemergence weed control. Can be used anytime until corn is 48" tall or until tasseling occurs. Apply to actively growing weeds before they reach the maximum height listed on the product label for each target weed species. Does not control grasses, but can be tank mixed with many other herbicides. See label for details. Do not exceed 1.25 oz/A per season. Do not apply to crop under stress or injury may occur.

nicosulfuron (Accent Q): *REI 4h, Group 2.* Apply 0.45 to 1.8 oz/A. Postemergence grass herbicide. Works on grasses only. Best results are obtained when broadcast applied to young, actively growing grasses before corn is 12" tall. If corn is 12" to 18" high, applications should be made with drop nozzles. Applications must include either a non-ionic surfactant or crop oil concentrate. An ammonium nitrate nitrogen fertilizer must also be used unless the label of a potential tank mix partner prevents it. Do not apply if corn is greater than 18" or 5 leaf collars. Not all sweet corn varieties are tolerant to Accent. Check with the Dupont representative or Extension for further information. Also see the label for optimum sizes of grasses.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

tembotrione (Laudis): REI 12h, Group 27. Apply 3 fl oz of Laudis per acre postemergence to control many annual broadleaf weeds, including common lambsquarter and triazine-resistant broadleaf weed biotypes, and many annual grasses. Add oil methylated seed oil (MSO) or concentrate (COC) to be 1% of the spray solution (1 gal/100 gals of spray solution). In addition, the label requires the addition of nitrogen liquid fertilizer (1.5 qt/A) or AMS (1.5 lb/A). Tank mix with 0.25 to 1 lb ai/A of atrazine for improved control and to broaden the spectrum of weeds control. Local university data supports the use of at least 0.5 lb ai/A of atrazine.

Do not apply tank-mixes of Laudis and atrazine to corn greater than 12" tall. Do not use postemergence if Callisto, Lumax or Lexar was used preemergence. Do not tank-mix with Callisto. Laudis will control/suppress most annual grass species, but may not control certain grass species or grasses larger than the maximum recommended size when treated. Fall panicum is not controlled by Laudis. Most broadleaf weeds should be treated before they are 6" tall and grass weeds should be treated before 2" in height. Laudis has up to an 18 month replant restriction for many vegetables.

topramezone (Armezon): PHI 45d, REI 12h, Group 27. Absorbed by leaves, roots, and shoots and translocated to the growing points of sensitive weeds to control emerged weeds. Crops under stress may show transient bleaching. These symptoms are temporary and occur infrequently. Apply up to 1 oz/A when weeds are actively growing, up until corn stage V8. Controls many annual broadleaf weeds, including common lambsquarter and triazine-resistant broadleaf weed biotypes, and annual grasses. Postemergence applications of Armezon require the addition of an adjuvant (crop oil concentrate) and nitrogen fertilizer for optimum weed control. Do not use postemergence if Callisto, Lumax or Lexar was used preemergence due to herbicide resistance concerns. Will control/suppress annual grass species and broadleaf weeds, but may not control species when larger than the maximum recommended size for treatment. Most broadleaf weeds should be treated before they are 6" tall and grass weeds should be treated before 2" in height. Use the higher rate to suppress or control panicum species or in rescue applications where the target weeds have grown beyond the size indicated on the label. Can be tank mixed with 0.25 to 1 lb ai/A of atrazine for improved control and to broaden the spectrum of weeds control. Local university data supports the use of at least 0.5 lb ai/A of atrazine.

■ Perennial Weed Control

Several perennial weed species, including quackgrass, bindweed and milkweed, may be present in a corn field. The grass and broadleaf herbicides described above will have limited activity on these weeds. Use of glyphosate as described below can provide excellent control of these perennial weed species.

glyphosate (Roundup Power Max): REI 12h, Group 9. Apply as a spot treatment BEFORE silking of corn. Do not treat more than 10% of the total field area to be harvested. Any crop plants receiving spray in the treated area will be killed.

Apply AFTER corn harvest to actively growing quackgrass 6" to 8" high. Wait at least 5 days and then plow. Do not

plant subsequent crops other than those on the label for 30 days following application. Most effective on bindweed and milkweed at or after bloom.

■ Mixing Herbicides for Weed Control in Sweet Corn

Many corn herbicides can be tank mixed with one or more other herbicides to extend the spectrum of weed control. Labels will have detailed instruction about compatible tank mixing partners and instructions on selecting rates, etc. when tank mixing.

■ Formulated Mixes (Prepackaged Tank Mixes)

In recent years, many products have come on the market as prepackaged combinations of herbicides which were often recommended in the past as tank-mix combinations of products purchased separately. They are designed for to expand the spectrum of control (i.e. grass herbicide mixed with broadleaf herbicide).

There are 3 questions that a grower or pesticide applicator should ask when deciding whether to use a formulated mix or the individual herbicide.

1. Which is less expensive on a per acre basis?
2. Which formulation is easier to apply? Most pesticide applicators prefer to avoid wettable powders, for example.
3. Is the ratio of the two herbicides in the formulated mix appropriate for the given field situation? For example, Bicep Lite contains 2/3 as much atrazine as Bicep and should allow growers a better opportunity to obtain good grass control without using more atrazine than is needed.

Following are some examples of formulated mixes registered for use on sweet corn. There are many others in addition to those listed.

Formulated Mix	individual Herbicides Contained in Mix
Acuron	atrazine (Aatrex, Group 5) + s-metolachlor (Dual, Group 15) + mesotrione (Callisto, Group 27) + Bicyclopyrone
Anthem	fluthiacet-methyl (Cadet, Group 14) + pyroxasulfone (Zidua, Group 15)
Armezon Pro	topramezone (Armezon, group 27) + dimethenamid (Outlook, Group 15)
Bicep Magnum Bicep Lite Magnum (Aatrex)	metolachlor (Dual, Group 15) + atrazine (Aatrex, Group 5)
Laddock	bentazon (Basagran, Group 6) + atrazine (Aatrex, Group 5)
Lexar and Lumax	atrazine (Aatrex, Group 5) + metolachlor (Dual, Group 15) + mesotrione (Callisto, Group 27)

CUCUMBER, MUSKMELON, AND WATERMELON

Cucumbers and muskmelons (genus *Cucumis*) and watermelons (genus *Citrullus*) are related crops of tropical origin that have similar cultural requirements. All three are tender, warm season vegetables that will not tolerate chilling or soil temperatures below 55°F. Having a good rotation plan is particularly important for these crops, as they are susceptible to several soilborne pathogens such as *Phytophthora* blight, scab and angular leaf spot.

Types and Varieties

Cucumber types include pickling (short, with spines), slicing (long, with spines), and beit alpha types (long, with tender spineless skins). Cucumbers used for greenhouse or tunnel production should be parthenocarpic, meaning that they set fruit without pollination. Muskmelons have orange, musky flesh, and are the most common type of melon grown in New England. Specialty melons with white or green flesh include casaba, crenshaw and honeydew types. Watermelons exhibit a range of flesh colors (red, yellow, orange) and both seeded and seedless varieties are available.

Soil Fertility

Soils that warm up quickly in the spring are preferred over heavier soils that remain cool. Muskmelon should be grown on very well-drained soil for optimum quality. Raised beds provide additional benefits. The soil should be fertile and high in organic matter. On sandy soils, irrigation is necessary. In non-irrigated fields, apply the lower rates of fertilizer recommended.

Apply lime according to soil test to maintain soil pH at 6.0-6.8. Watermelon can tolerate pH as low as 5.5. If the fertilizer cannot be banded at planting, add the band fertilizer amount to preplant broadcast application. If growing plants on plastic mulch, nitrogen can be applied through trickle or overhead irrigation or sidedressed along the edge of the plastic mulch. Nitrogen under the plastic mulch is protected from leaching. Foliar feeding rate is 8-10 lb actual N (4-5 lb urea) per acre. Wet foliage is conducive to disease development, so avoid foliar feeding after the 5 leaf stage.

If using transplants, use of a liquid starter fertilizer at planting time is beneficial, especially with cool soil conditions. Use a starter fertilizer mixed at a rate of 2 lb/50 gal water. Apply 8 fl oz (1 cup) per transplant.

Planting

Cucumbers may be direct seeded or transplanted. Because of the long season required for muskmelon and watermelon, transplants are used. Transplants are preferred for early crops.

Cucumber, Muskmelon and Watermelon Varieties	
<p>Pickling Cucumber Alibi (50) – CMV, PM, S Citadel (52) – A, ALS, CMV, DM, PM, S Eureka (57) - A, ALS, CMV, PM, PV Supremo (56) - A, ALS, CMV, PM, PV, S Vlasstar (52) - A, AI, CMV, PM, S</p>	<p>Slicing Cucumber Bristol (54) – A, ALS, CMV, DM, PM, S Dasher II (58) - A, ALS, CMV, PM, S General Lee (66) – CMV, PM, S Intimidator (61) - A, ALS, CMV, PM, S Marketmore 76 (58) - CMV, PM, S, OP Speedway (56) - A, ALS, CMV, PM, S</p>
<p>Protected Culture/High Tunnel Cucumber Corinto (slicing - 48) – CMV, PM, P Excelsior (pickling - 50) – ALS, CMV, PM, S, P Katrina (beit alpha - 49) - CMV, PM, S, P Lisboa (slicing - 45) – CMV, PM, S, P Socrates (beit alpha - 52) - PM, S, P Tyria (beit alpha - 56) – PM, S, P Unistars (pickling - 42) – PM, S, P</p>	<p>Specialty Melon Diplomat (71) - PM San Juan (78) - F012, PM Sun Jewel (68) – DM, PM</p>
<p>Watermelon - Seeded Crimson Sweet (85) - A, F012, OP Sugar Baby (80) - OP Sangria (87) – F1, A</p>	<p>Muskmelon Athena (79) - F012, PM Goddess (68) – F012, PM Gold Star (87) - F012 Sarah's Choice (76) - F012, PM Wrangler (76) - F012, PM</p>
	<p>Watermelon - Seedless Gypsy (82) - A Sorbet (80) – A, F01</p>
<p>The number in parentheses is the approximate number of days to maturity from seeding. Resistant or tolerant to: A: Anthracnose; ALS: Angular Leaf Spot, DM: Downy Mildew (current races only), CMV: Cucumber Mosaic Virus, F: Fusarium (races indicated where known), PM: Powdery Mildew, PV: Potyviruses, S: Scab Other codes: OP: open-pollinated, P: Parthenocarpic (sets fruit without pollination)</p>	

Plant Nutrient Recommendation According to Soil Test Results for Cucumber, Muskmelon, and Watermelon

CUCUMBER, MUSKMELON, AND WATERMELON*	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P₂O₅ per acre				Potassium (K) Lbs K₂O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate (Transplants)	50	110	60	0	0	150	90	0-40	0
Band-Place when Direct Seeding**	20-40	40	40	25-50	0	30	30	30	0
Sidedress When Vines Start to Run***	20-40	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	80-130	150	100	25-50	0	180	120	30-70	0

* Watermelon requires a maximum of 100 lbs/A of N; excessive N may cause hollow heart in seedless varieties.

** For direct-seeded cucumbers. For melon transplants, add the band fertilizer amount to pre-plant broadcast application. Total N and K₂O in the band should not exceed 5.5 lb./1000' of row. Banded P₂O₅ may not be of benefit in warm soils.

*** Sidedressing may not be necessary when using plastic mulch, or if organic matter can supply sufficient N; repeat sidedress in 2 to 3 weeks

The plants should be about 3 weeks old, with just 1 to 2 true leaves, at transplanting time. Older transplants that have begun to run are difficult to handle and suffer greater transplant shock.

Recommended spacing for slicing cucumbers, muskmelons and watermelons is 2' between plants and 6' between rows. Pickling cucumbers should be direct seeded to 6"-8" between plants and 3'-6' between rows, depending on the cultivar. Most cultivars should be planted at 3' between rows.

Seedless watermelons require special growing conditions. Seedless cultivars are sterile because they are triploid, and this negatively affects their germination ability. They require high temperatures (85°-95°F.) during germination, and excess soil moisture should be avoided. To ensure fruit set, a male pollenizer variety must be planted among seedless watermelons in a ratio of at least 1 pollenizer to 3 seedless plants.

In some growing seasons, vine crops that have recently been transplanted or have just germinated suddenly wilt and die. Most often, this situation occurs just following a period of 4-5 days of rainy or cloudy weather. Without sunshine, soil temperatures drop below 55°-60°F. At these soil temperatures the plant roots cannot absorb water from the soil. Consequently, when the sun does reappear, water transpires from the leaves much more rapidly than the roots absorb water, resulting in sudden wilting and death. There is no control for this problem, except to attempt to manipulate planting around weather forecasts. Earlier planting dates increase the likelihood of this problem.

Field Culture

Early and total yields are increased with black plastic mulch. For summer plantings when day time temperatures are 85°F or greater, more growers are using white plastic mulch to avoid high soil temperatures that develop under black plastic and cause sunburn or crop loss on delicate transplants. Before the plastic is laid, be sure the soil is fertilized and the soil surface is smooth. The plastic should fit snugly against the surface. Do not lay plastic on dry soil; either irrigate or wait for rain to ensure the soil is moist prior to laying the mulch. In conjunction with plastic mulching, using hoops and spunbonded row covers will provide earlier and higher yields, while also helping to control insects such as striped cucumber beetle. Apply the covers at the time of planting and leave on until the time for pollination by bees (bloom). These crops can withstand high temperatures under the covers. A sufficient number of pollinating insects should be present to ensure adequate fruit set in cucumber and melons. One strong hive of honeybees per acre as flowers just begin to open is recommended.

Harvest and Storage

Cucumber. Harvest on a regular basis (2-4 times per week) to obtain a maximum number of fruits. Cucumbers are sensitive to chilling injury; optimum storage temperature is 50°-55°F.

Muskmelon. Unless they are to be shipped, harvest at full slip, when a slight twist of the melon will cause the stem to separate from the vine. Only well-netted muskmelons should be harvested; fruits with poor netting have generally been stunted in growth and lack good flavor. Hold muskmelons for 1-2 days at 70°F for final ripening; for longer periods of storage, maintain a temperature of 50°-55°F.

Watermelon. Varieties vary in maturity indicators. The proper time to harvest must be learned by experience (and perhaps by wasting a few fruits). Dried (brown) tendrils and ground spots are two generally reliable indicators of ripeness. When the tendril on the vine at the juncture of the fruit stem turns brown, the watermelon is close to maturity. A bright yellow ground spot on the underside of the fruit also indicates maturity. The thumping method to identify ripe melons can work, after some experience is developed. Store watermelons at 50°-55°F.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

PESTICIDE USE IN GREENHOUSES AND HIGH TUNNELS:

Pesticides can be used on high tunnel and greenhouse crops if: 1) the crop and pest/disease is on the label, AND the products specifically says it can be used in the greenhouse; OR 2) the crop and pest/disease is on the label, AND the product is 'silent' about use in the greenhouse in the greenhouse. Products that specifically prohibit greenhouse use cannot be used in greenhouses or high tunnels regardless of the crops or pests/diseases listed on the label.

■ Anthracnose (*Colletotrichum*), Alternaria Leaf Spot, and Black Rot (*Didymella*)

Plant only certified disease-free seed. Rotate out of cucurbits for at least 2 years. Control all weeds, especially volunteer cucurbits. Collect and burn or plow down deeply all infected crop debris after harvest. Grow cultivars with resistance if available. Avoid wounding fruit during harvesting. Immerse fruit in clean and fresh water containing 120 ppm chlorine. Chemical control can be obtained through a regular spray program of eradicant or protective fungicides. Coverage of leaf undersides and fruit is crucial to success.

azoxystrobin (Quadris): 11.0 to 15.5 fl oz/A; PHI 1d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides.

azoxystrobin plus chlorothalonil (Quadris Opti): 3.2 pt/A; PHI 1d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; PHI 1d, REI 12h, Groups 11 & 3.

boscalid (Endura): 6.5 oz/A; PHI 0d, REI 12h, Group 7. Not labeled for anthracnose.

chlorothalonil (Bravo Weather Stik): 1.5 to 3.0 pt/A; PHI 0d, REI 12h, Group M5. Bravo WS can cause injury to watermelon fruit; see label.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 7d, REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Tank mix with an appropriate contact fungicide with a different mode of action. Not labeled for black rot.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 14d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides. For *Alternaria* only.

fluopyram plus tebuconazole (Luna Experience): 6.0 to 17.0 fl oz/A; PHI 7d, REI 12h, Groups 7 & 3. Watermelon only.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; PHI 5d, REI 24h, Group M3. Some cantaloupe varieties are sensitive.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; PHI 5d, REI 48h, Groups M3 & M1.

penthiopyrad (Fontelis): 12.0 to 16.0 fl oz/A; PHI 1d, REI 12h, Group 7. Not labeled for anthracnose.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

potassium bicarbonate (MilStop^{OC}): 2.5 to 5.0 lb/100 gal; PHI 0d, REI 4h, Group NC. See label for small volume application rates.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11.

pyraclostrobin plus boscalid (Pristine): 12.5 to 18.5 oz/A; PHI 0d, REI 12h, Groups 11 & 7. Do not make more than one application of Pristine before alternating with a non-Group 11 fungicide.

thiophanate methyl (Topsin M 70WP): For anthracnose and black rot only, 0.5 lb/A; PHI 0d, REI 24h, Group 1. The repeated exclusive use of Topsin M may lead to buildup of resistant strains of fungi and loss of disease control.

■ Downy Mildew (*Pseudoperonospora cubensis*)

Pseudoperonospora cubensis infects only members of the cucurbit family and is an obligate parasite. Its survival depends on the presence of cucurbit hosts, either in climates which permit their growth year round or in greenhouse culture. The source of primary inoculum in cold climates is windblown sporangia from areas where plants survive the cold season. Generally, downy mildew of cucurbits does not arrive in southern New England until September. However, in some seasons it can move up the eastern seaboard early and arrive in July. The progress of downy mildew is tracked by the North American Plant Disease Forecast Center and warnings issued based on disease progression and weather (<http://cdm.ipmpipe.org/>). Physiological specialization occurs in *P. cubensis* and at least 5 pathotypes have been described. Cucumber and melon are susceptible to all pathotypes, while squash and melon cultivars vary in their reactions. Spread of downy mildew within a field can be by air currents, rain splash, workers, and tools. The main means of control are fungicide applications, the use of resistant cultivars, and

cultural practices. Maximum control can be achieved only with a combination of these measures. Maximize the distance from potential inoculum sources. Use plant spacing which reduces the density of the plant canopy. Avoid overhead irrigation. Both these practices are aimed at minimizing the length of leaf wetness periods. Some commercial cultivars of cucumber have good levels of resistance to downy mildew. Watermelon and melon cultivars are available with low levels of resistance. Squash and pumpkin cultivars are resistant to some pathotypes but are very susceptible to compatible pathotypes.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 and 40.

azoxystrobin plus chlorothalonil (Quadris Opti): 3.2 pt/A; PHI 1d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OC}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

chlorothalonil (Bravo Weather Stik): 1.5 to 2.0 pt/A; PHI 0d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

cyazofamid (Ranman): 2.1 to 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Alternate sprays of Ranman with a fungicide with a different mode of action.

cymoxanil (Curzate 60 DF): 3.2 to 5.0 oz/A; PHI 3d, REI 12h, Group 27. Use only in combination of a labeled rate of a protectant fungicide (copper, chlorothalonil, mancozeb).

dimethomorph (Forum): 6.0 fl oz/A; PHI 0d, REI 12h, Group 40. Apply only in combination with a labeled rate of another non-group 40 fungicide. Do not make more than 2 sequential applications of Forum before alternating to a fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Tank mix with an appropriate contact fungicide with a different mode of action.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 14d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

fluazinam (Omega 500F): 15.35 fl oz/A; PHI 7d, REI 48h, Group 29. Cabbage and Chinese cabbage only.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. A tank mix with another labeled fungicide with a different mode of action (FRAC #) must be used for resistance management.

fosetyl- Al (Aliette WDG): 2.0 to 5.0 lb/A; PHI 0d, REI 12h, Group 33. Do not tank mix with copper products or apply in a spray solution with a pH less than 6.0.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; PHI 5d, REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; PHI 5d, REI 48h, Groups M3 & M1.

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; *PHI 5d, REI 48h, Groups M3 & 22*. Apply preventively to control downy mildew. Do not tank mix with other fungicides if the target pest is only downy mildew.

oxathiapiprolin (Orondis Ultra A): 2.0 to 4.8 fl.oz/A; *PHI 0d, REI 4h, Group 49*. Begin foliar application prior to disease development. Use higher rate when disease is present.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that heat or moisture stressed. Do not apply directly to copper treated plants within 20-day interval to avoid plant injury.

propamocarb HCl (Previcur Flex): 1.2 pt/A; *PHI 2d, REI 12h, Group 28*. Alternate with a contact fungicide (copper, chlorothalonil, sulfur).

zoxamide + chlorothalonil (Zing!): 36 fl oz/A; *PHI 0d, REI 12h, Groups 22 & M5*.

■ *Phytophthora* Blight and Fruit Rot

Phytophthora capsici cannot be managed by fungicide applications alone; successful disease control is achieved only by a season-long effort to manage water and other cultural practices. The single most effective way to control this disease is to prevent its movement into clean fields by equipment, humans, or infested water. Plant susceptible crops (tomatoes, peppers, eggplant, and all cucurbit species) in fields that have no history of this disease and are well-drained. Plant non-vining crops on raised beds, avoid planting in low areas where water puddles, and improve drainage by sub-soiling after heavy rain events. Promptly disk under small areas where the disease appears along with a border of healthy appearing plants. Avoid working in wet fields and compacting the soil.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; *PHI 0d, REI 12h, Groups 45 and 40*.

cyazofamid (Ranman): 2.75 fl oz/A; *PHI 0d, REI 12h, Group 21*. Addition of a surfactant improves effectiveness when disease pressure is severe. Alternate sprays of Ranman with a fungicide with a different mode of action. Observe a 30-day plant back interval for crops not on label.

dimethomorph (Forum): 6 fl oz/A; *PHI 0d, REI 12h, Group 40*. Apply only in combination with a labeled rate of another non-group 40 fungicide. Do not make more than 2 sequential applications of Forum before alternating to a fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8 to 10 oz/A; *PHI 3d, REI 12h, Groups 11 & 27*. Suppression ONLY. Foliar or fruit phase ONLY. Tank mix with an appropriate contact fungicide. Do not alternate with other Group 11 fungicides.

fluazinam (Omega 500F): 15.35 fl oz/A; *PHI 7d, REI 48h, Group 29*. Cabbage and Chinese cabbage only.

fluopicolide (Presidio): 3 to 4 fl oz/A; *PHI 2d, REI 12h, Group 43*. A tank mix with another labeled fungicide with a different mode of action is required.

fosetyl Al (Aliette WDG): 2 to 5 lb/A; *PHI 0d, REI 12h, Group 33*. Do not tank mix with copper compounds. Mixing Aliette with surfactants or foliar fertilizers is not recommended. Use the high rate when *Phytophthora* blight is active.

oxathiapiprolin (Orondis Ultra A): 2.0-4.8 fl.oz/A; *PHI 0d, REI 4h, Group U15*. Begin foliar application prior to disease development.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that heat or moisture stressed. Do not apply directly to copper treated plants within 20-day interval to avoid plant injury.

■ Powdery Mildew (*Podosphaera xanthii*)

Fungicides should be applied at the first sign of disease (or earlier with some products). Begin scouting for powdery mildew at fruit initiation. On cucurbits, powdery mildew fungi attack both the top and bottom of the leaf, and this makes the disease more difficult to control with non-systemic fungicides. However, powdery mildew fungi tend to become resistant to systemic fungicides such as Topsin-M (Group 1); Cabrio, Flint Extra, Quadris and Sovran (Group 11). Resistance to Group 1 and Group 11 fungicides has resulted in the removal of these classes of fungicides from recommendations, with the exception of Pristine which is a combination product. Resistance to the DMI fungicides (Rally, Procure) is also widespread; use Rally or Procure at the high labeled rate only. The most effective contact fungicides are sulfur, mineral oil, and chlorothalonil. Begin applying fungicides when powdery mildew is at a low level (threshold is 1 of 50 old leaves with symptoms on either leaf surface) or on a preventative schedule for fields not scouted; do not begin using mobile fungicides when disease is widespread. A seven-day interval is recommended.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; *PHI 0d, REI 4 h, Group 44*. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

boscalid (Endura): 6.5 oz/A; *PHI 0d, REI 12h, Group 7*. Suppression only.

***Reynoutria sachalinensis* extract (Regalia^{OG}):** 1.0 to 4.0 qt/A, foliar or ground application; *PHI 0d, REI 4 h, Group P5*. Apply to ensure thorough coverage. See label for specific application instructions.

botanical extract (Ecoswing^{OG}): 1.5-2.0 pt/A; *PHI 0d, REI 4h*.

chlorothalonil (Bravo Weather Stik): 2 to 3 pt/A; *PHI 0d, REI 12h, Group M5*. Use caution when applying to watermelon: see label.

copper hydroxide (Kocide 3000): 0.5 to 1.25 lb/A; *PHI 0d, REI 48h, Group M1*. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12*.

cyflufenamid (Torino): 3.4 oz/A; *PHI 0d, REI 4h, Group U6*.

difenoconazole plus cyprodinil (Inspire Super): 16 to 20 fl oz/A; *PHI 7d, REI 12h, Group 3 & 9*.

fluopyram plus tebuconazole (Luna Experience): 6.0 to 17.0 fl oz/A; *PHI 7d, REI 12h, Groups 7 & 3*. Watermelon only.

flutriafol (Rhyme 2.08 SC): 5-7 fl oz/A; *PHI 0d, REI 12h, Group 3*.

mineral oil (JMS Stylet-oil^{OG}): 3 to 6 qt/A; *PHI 0d, REI 4h, Group NC.*

metrafenone (Vivando): 15.4 fl oz/A; *PHI 0d, REI 12h, Group U8.*

potassium dihydrogen phosphate (Nutrol): 8 to 12 lb/A; *PHI 0d, REI 4h, Group NC.*

myclobutanil (Rally): 2.5-5.0 oz/A; *PHI 0d, REI 24h, Group 3.*

penthiopyrad (Fontelis): 12.0 to 16.0 fl oz/A; *PHI 1d, REI 12h, Group 7.*

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19.*

potassium bicarbonate (Kaligreen^{OG}): 2.5 to 5.0 lb/A; *PHI 1d, REI 0h, Group NC.*

quinoxifen (Quintec): 4 to 6 fl oz/A; *PHI 3d, REI 12h, Group 13.* Melon only. Alternate with other effective fungicides at their recommended rates and spray intervals.

sulfur (Microthiol Dispers^{OG}): 2 to 4 lb/A; *PHI 0d, REI 24h, Group M2.* Sulfur can injure plants, especially when temperatures reach 90°F. Do not apply to sulfur sensitive varieties.

triflumizole (Procuré 480SC): 8 oz/A; *PHI 0d, REI 12h, Group 3.* Alternate with a protectant fungicide (copper, chlorothalonil, mancozeb, sulfur).

triflumizole (Trionic 4 SC): 2 to 4 fl oz/100 gal.; *PHI 1d, REI 12, Group 3.* Apply only as foliar spray. See label for surfactant recommendation. Labeled for greenhouse use.

■ Scab (*Cladosporium cucumerinum*)

Scab is a significant problem for summer and winter squash, pumpkin, melon, and watermelon. Resistant cultivars of cucumber are widely available. The pathogen survives in the soil on infected crop debris, may be seedborne, and is capable of saprophytic growth. Rotate with non-cucurbit crops for 2 to 3 years. Select sites with well-drained soil and good air movement for rapid drying of foliage and fruit. Avoid overhead irrigation and dense plant canopies. Fungicide sprays may not be effective during extended cool, wet weather due to the short disease cycle of this pathogen.

acibenzolar-S-methyl (Actigard): 0.5 to 1.0 oz/A; *PHI 7d, REI 12 h, Group P1.*

chlorothalonil (Bravo Weather Stik): 2.0 to 3.0 lb/A; *PHI 0d, REI 12h, Group M5.* Use caution when applying to watermelon: see label.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; *PHI 5d, REI 24h, Group M3.*

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; *PHI 5d, REI 4h, Groups M3 & M1.*

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19.*

■ Seed Decay

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

fludioxonil (Maxim 4FS): 0.08 to 0.16 fl oz/100 lb seed; *REI 12h, Group 12.* For protection against seed and soil-borne fungi.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/lb seed; *REI 48h, Group 4.* For Pythium damping-off protection.

thiram (Thiram SC): 4.5 fl oz/100 lb seed; *REI 12h, Group M3.*

■ Angular Leaf Spot (*Pseudomonas syringae* pv. *lachrymans*)

Avoid working in the fields when the foliage is wet. Plow crop residue under promptly after harvest to aid decomposition. Rotate out of cucurbits for 2 years. Plant resistant varieties when possible. Use pathogen-free seed or hot-water treat the seed to kill the bacterium in the seed. Sprays may not be effective if applied too late or if environmental conditions are conducive to spread of the disease.

copper hydroxide (Kocide 3000): 0.5 to 1.25 lb/A; *PHI 0d, REI 48h, Group M1.* Do not apply in a spray solution having a pH less than 6.5. or tank mix with Aliette.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 3.0 lb/A; *PHI 5d, REI 48h, Groups M3 & M1.*

■ Bacterial Wilt (*Erwinia tracheiphila*)

Bacterial wilt is transmitted by cucumber beetles. Cucumber and muskmelon are highly susceptible to wilt; watermelon is not. Seedlings at the cotyledon and 1- to 3-leaf stage are more susceptible to infection with bacterial wilt than older plants. Thus, it is especially important to keep beetle numbers low before the 5-leaf stage. Cucumber beetles must be controlled by appropriate insecticide programs. Please refer to the information on cucumber beetle for management recommendations. Use crop rotation to reduce beetle numbers. Because this bacterium is transmitted systemically by cucumber beetles, copper sprays are of no value. Rogue infected plants. Resistant cultivars of cucumber are being developed. No resistance has been identified in melon.

■ Cucumber Mosaic Virus (CMV)

Many different strains of this virus occur and the host range includes plants in more than 31 different families. Many weed species also serve as hosts and the virus is seed-borne in chickweed. The virus is spread by more than 40 species of aphids and 2 beetles. Seed transmission is possible but unlikely in commercial cucumber seed. The abundance of other host plants, their proximity to crops, and the presence of vectors govern the incidence and severity of disease. The use of resistant varieties is the most effective means of control. Reduce weeds, especially chickweed, pokeweed and milkweed, as much as practical. Practice rotation and plant away from previously contaminated fields. Insecticides are not effective.

■ Watermelon Mosaic Virus (WMV) and Papaya Ringspot Virus (PRSV-W)

Several aphid species transmit these 2 viruses. PRSV-W is only known to occur in the cucurbit family but WMV-II has been reported from alfalfa, vetch, crimson clover, sour clover, snow-on-the-mountain and *Malva parviflora*. Seed transmission is considered a possibility but remains unproven.

■ Zucchini Yellow Mosaic Virus (ZYMV)

Zucchini Yellow Mosaic Virus was first discovered in the United States in the early 1980s. Two strains, Connecticut and Florida, are currently recognized. The Connecticut strain produces more severe symptoms than the Florida

strain. The virus is transmitted in a nonpersistent manner by aphids. At this time, no weed hosts have been identified. Resistant varieties are not available.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Caution: Insecticides should not be applied when bees are active in the field. Avoid products with high or moderate bee toxicity during bloom. If application of an insecticide is necessary while the crop is blooming, select products with low bee toxicity or with short residual period; apply in the evening after the bees have left the field. See Protecting Honeybees and Native Pollinators in the Insect Management section for more suggestions on how to avoid harmful effects on pollinators.

■ Aphids, Green Peach (*Myzus persicae*) and Melon (*Aphis gossypii*)

Aphids found in cucurbits include green peach aphid and melon aphid. See Peppers for more information about green peach aphid. Melon aphid has a wide host range; vegetable crops attacked include cucurbits, asparagus, pepper, eggplant and okra. Among cucurbits, it is more serious on cucumber, muskmelon and watermelon than in squash and pumpkins. Varieties differ in susceptibility. Melon aphid overwinters in the north on woody plants including catalpa and rose of Sharon; more southerly, adults survive on cold tolerant plants including spinach and dock. Life cycle is similar to green peach aphid; winged females colonize crops in early summer, and wingless females produce live young for about 15 days (70 to 80 offspring per female) resulting in multiple generations. The time from birth to reproductive adult can be 1 week. Wingless females are 1 to 2 mm long. Color varies from light green mottled with dark green (most common) to white, yellowish or dark green. The cornicles at the tip of the abdomen are always black, a key diagnostic feature. Melon aphid outbreaks are more common in hot, dry weather.

Infestations occur on undersides of leaves where aphids extract plant sap with their piecing sucking mouthparts. Feeding causes yellowing, puckering, leaf curling, and leaf death at high numbers along with shiny honeydew deposits and buildup of sooty mold. Viruses transmitted by melon aphid include cucumber mosaic, watermelon mosaic, and zucchini yellow mosaic. Because transmission occurs within 15 seconds of feeding, insecticides may not prevent initial virus infection though they may reduce its spread in the crop. Oils may reduce virus transmission but test for phytotoxicity.

Use of reflective or row covers to prevent early infestation and virus transmission. Reflective mulch confuses aphid orientation and reduces their ability to locate and infest plants. Direct seeding is recommended in reflective mulch for maximum effectiveness. When using row cover, apply immediately after setting transplants or seeding, and be sure transplants were not infested while in the greenhouse. Cultivars differ in susceptibility to aphid buildup and to virus; plant resistant varieties if they are available. Separate early and late plantings.

Scout for aphids beginning in mid-June by searching undersides of leaves on runners. If 20% of runners or more have live aphids treatment may be needed. Good coverage of undersides of leaves is needed with materials that require direct contact with pest; translaminar products help to reach aphid feeding sites. Use selective insecticides for other pests to conserve natural enemies.

alpha-cypermethrin (Fastac* EC): 3.4 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

acetamiprid (Assail 30 SG): 2.5 to 4 oz/A; PHI 0d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 3 fl oz/A; PHI 0d, REI 12 h, Group 9D.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A cotton and melon aphid, 10 to 13.5 oz/A green peach aphid; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, or drip chemigation during first half of crop growing cycle.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

dimethoate (Dimethoate 4EC): 0.5 to 1 pt/A for watermelon; 1 pt/A for other melons; PHI 3d, REI 48h, Bee: H, Group 1B. Do not use on cucumbers.

dinotefuran (Safari 20SG): 0.16 to 0.32 oz/1,000 sq ft; 3.5 to 7 oz/100 gal; 7 to 14 oz/A; REI 12h, Bee: H, Group 4. Cucumber and melon transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. Do not apply to vegetables grown for seed.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol + 3 to 4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; 2.8 to 4.28 oz/A or 0.065 to 0.1 oz/1000 sq ft for greenhouse cucumbers; *PHI 0d, REI 12, Bee: L, Group 9C.*

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; *PHI 1d foliar, PHI 11d soil, REI 4b, Bee: L, Group 4D.*

gamma-cyhalothrin (Declare*): 1.54 oz/A; *PHI 1d, REI 24b, Bee: H, Group 3A.*

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; 0.44 fl oz/10,000 plants on seedling transplants in greenhouse; *PHI 21d, REI 12b, Bee: H, Group 4A.* Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection. Not for foliar applications.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12b, Bee: L.* Spray to wet all infested plant surfaces. May require repeated applications. Apply with a labeled companion insecticide on green peach aphids; on other aphids, use of a companion insecticide is recommended for enhanced and residual control.

lambda-cyhalothrin (Warrior* II): 1.92 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.*

malathion (Malathion 57 EC): 1.5 pt/A; *PHI 1d, REI 24h cucumber, 12h melons, Bee: H, Group 1B.* Do not apply unless plants are dry.

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 1d for 1.5 pt/A; PHI 3d for over 1.5 pt/A, REI 48h, Bee: H, Group 1A.* For melon aphid.

oxamyl (Vydate* L): 2 to 4 pt/A; *PHI 1d, REI 48h, Bee: H, Group 1A.*

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; *PHI 0d, REI 12b, Bee: L, Group 9A.* Selective control of aphids including melon and green peach aphid. Translaminar. Apply before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12b, Bee: M, Group 3A.*

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils.

thiamethoxam (Actara): 1.5 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray.

tolfenpyrad (Torac): 17 to 21 fl oz/A; *PHI 1d, REI 12 h, Bee: H, Group 21A.*

■ **Cucumber Beetle, Striped (*Acalymma vittatum*) and Spotted (*Diabrotica undecimpunctata*)**

Striped cucumber beetle is a key pest of all cucurbit crops in New England, one that requires cultural and often chemical

controls to prevent direct feeding damage and transmission of bacterial wilt. Adult beetles are 7 mm long, are yellow with 3 black stripes that reach the end of the forewings, and have a yellow thorax and black head. Adults overwinter primarily in field edges near last year's crop, with a small proportion remaining in the field. With the onset of warm days (> 50°F), beetles feed on pollen in early-blooming wild plants. High tunnel and greenhouse cucumbers draw beetles first, followed by early field crops. Eggs are laid in soil at the base of the stem, and larvae feed on roots. After pupation in the soil, 'summer adults' emerge, generally in late-July and August. Summer adults feed until early fall, when they move to overwintering sites. Some may produce a second generation which emerges in the fall. There is one generation per year in northern New England and a partial second generation in southern New England.

Beetles can colonize a field very rapidly. Adults cause direct feeding damage to cotyledons (often as gouges on underside), leaves (ragged holes) and the base of the stem (wounds and scars). Wounds on the stem allow entry of soil-borne pathogens. Once flowering begins, beetles congregate in flowers. At high numbers, adults may cause pits and scars on fruit. Larval root feeding, hidden but important, reduces plant vigor and yield. The striped cucumber beetle also vectors *Erwinia tracheiphila*, the causal agent of bacterial wilt. The pathogen overwinters in the beetle gut, and is transmitted through fecal material deposited in feeding wounds. The bacteria then invade the vascular system of the plant. Non-infected beetles can become infected by feeding on infected plants. Cucumber and muskmelon are highly susceptible to wilt; watermelon is not. Seedlings at the cotyledon and 1- to 3-leaf stage are more susceptible to infection with bacterial wilt than older plants. Thus, it is especially important to keep beetle numbers low before the 5 leaf stage.

Use crop rotation, moving spring crops as far as possible from last year's fields and overwintering areas. Exclude beetles by using use row covers, supported by hoops to prevent abrasion; remove at flowering to allow pollination. Use transplants so that plants reach at least the 3- to 4-leaf stage before beetles arrive. Some repellents or systemic insecticides may be applied to transplants outside the greenhouse before setting in the field, and some may be applied through drip irrigation. See cucumber beetle in the insect control section of Pumpkin, Squash and Gourds for information on using trap crops to protect a main crop of cucumbers and melons from beetle damage.

Scout twice per week from emergence to 3-leaf stage, then weekly. Count beetles per plant and note damage to leaves and stems. The economic threshold depends on the crop. To prevent bacterial wilt in highly susceptible crops such as cucumber, muskmelons, summer squash, and zucchini, treat when there is 1 beetle for every 2 plants. Less wilt-susceptible crops (butternut, watermelon, most pumpkins) will tolerate 1 or 2 beetles per plant without yield losses. Spray within 24 hours after the threshold is reached. Timely and effective early control will prevent the need for sprays during flowering when bees are active in the crop. There are few options for bee-friendly insecticides to use during flowering; if sprays are needed, apply in the evening after bees have stopped foraging.

Spotted cucumber beetle does not overwinter here but disperses from more southern areas, reaching New England in mid to late-summer. Also known as southern corn rootworm, it feeds in a very wide range of crops and weeds and is often found in flowers. Adults are yellowish green with 12 black spots and a black head. Immature stages are in the soil. This pest rarely builds up to damaging levels in New England.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

alpha-cypermethrin (Fastac* EC): 3.0 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

beta-cyfluthrin (Baythroid* XL): 2.4 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2 EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A. Do not apply when foliage is wet.

cryolite (Prokil Cryolite): 8 to 16 lb/A; PHI 14d, REI 12h, Bee: L, Group un. Melons only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 1 to 4 oz/A foliar; PHI 1d, REI 12 hr, Bee: H, Group 4A. Do not apply to vegetables grown for seed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay. Do not apply during bloom or if bees are actively foraging; PHI 21d, REI 24, Bee: H, Group 3. Control may be improved by the addition of a non-ionic surfactant.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 1/4 to 1/2 lb/gal for backpack sprayer; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 1/4 of its expected harvest size. Follow label instructions for mixing. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57 EC): 2 pt/A for watermelons, 1.6 pt/A for all other melons; PHI 1d, REI 12h, Bee: H, Group 1B. Melons only.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d for 1.5 pt/A, PHI 3d for over 1.5 pt/A, REI 48h, Bee: H, Group 1A.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

thiamethoxam (Actara): 3 to 5.5 oz/A; PHI 0d, REI 12h, Bee: H, Group 4.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray. Suppression only.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cutworms

See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 1.4 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OG}): 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Seedling spray only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. For variegated cutworm.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft; PHI 1d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants; reapply after heavy rain or at least every 2 to 4 weeks but not more than 3 times per 30 days.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Seedcorn Maggot (*Delia platura*)

See seedcorn maggot in the Beans insect control section for more information.

cyantraniliprole (Verimark): 10 to 13.5 oz/A soil; *PHI 1d, REI 4h, Bee: H, Group 28*. Apply as in-furrow spray or transplant tray drench no earlier than 72 hours prior to planting in field, or as transplant water treatment, hill drench, or surface band.

dimethoate (Dimethoate 4EC): 0.5 to 1 pt/A for watermelon; 1 pt/A for other melons; *PHI 3d, REI 48h, Bee: H, Group 1B*. Do not use on cucumbers.

■ Squash Bug (*Anasa tristis*)

See squash bugs in the insect control section of Pumpkin and Squash for more on life cycle, monitoring, and management.

acetamiprid (Assail 30 SG): 5.3 oz/A; *PHI 0d, REI 12h, Bee: M, Group 4A*. Most effective on newly laid eggs and nymphs.

alpha-cypermethrin (Fastac* EC): 3.0 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un*.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A*.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A*.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28*. Squash vine borer only.

carbaryl (Sevin XLR Plus): 1 qt/A; *PHI 3d, REI 12h, Bee: H, Group 1A*. Do not apply when foliage is wet. Apply sufficient spray volume for thorough coverage; time sprays for early morning or late afternoon. Repeated application may cause plant injury. For squash bug only.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A*. For squash bug only. Do not apply to vegetables grown for seed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A*.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; *PHI 21d, REI 24, Bee: H, Group 3*. Do not apply during bloom or if bees are actively foraging.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar; *PHI 1d, REI 4h, Bee: L, Group 4D*. Foliar applications only. Squash bug only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A*.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A*.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A*. Use high rate for squash bugs.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

Also known as Red Spider Mite. Outbreaks are often caused by the use of broad-spectrum insecticides that kill beneficial insects that normally keep two-spotted spider mites (TSSM) populations in check. Watch for white speckling on the upper surface of leaves or webbing on the undersurface around leaf veins. Avoid early-season, broad-spectrum insecticide applications for other pests. Use selective products whenever possible. With most miticides (not bifenazate), use 2 applications, approximately 5 to 7 days apart, to help control immature mites that were in the egg stage and protected during the first application. TSSM are prone to developing pesticide resistance so be sure to alternate between products after 2 applications to help prevent or delay resistance. For more information on TSSM, see the Eggplant section.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6*. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; *PHI 3d, REI 12h, Bee: L, Group 25*.

bifenthrin (Brigade* 2 EC): 5.1 to 6.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A*.

etoxazole (Zeal): 2 to 3 oz/A; *PHI 7d, REI 12h, Bee: L, Group 10B*. Do not apply more than once per season.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A; *PHI 7d, REI 24, Bee: H, Group 3*. Control may be improved by the addition of a non-ionic surfactant.

fenpyroximate (Portal XLO): 2 pt/A; *PHI 3d, REI 12 hr, Bee: L, Group 21A*. A selective contact miticide. Melons only.

gamma-cyhalothrin (Declare*): 1.54 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A*.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L*. Spray to wet all infested plant surfaces. May require repeated applications. Use of a companion labeled insecticide is recommended for enhanced and residual control.

malathion (Malathion 57 EC): 1.5 pt/A; *PHI 1d, REI 12h, Bee: H, Group 1B*. Melons only.

***Metarhizium anisopliae* Strain F52 (Met 52 EC):** 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L*.

neem oil (Trilogy^{OG}): 0.5 to 2% solution in 25 to 100 gal water/A; *PHI 0d, REI 4h, Bee: M, Group 18*. Avoid mid-day applications and ensure good coverage.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25*. Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; *PHI 7d, REI 12h, Bee: M, Group 23*. Complete coverage is necessary; an adjuvant may be used to improve coverage and control. Effective against egg and nymphal stages.

■ Whiteflies

See whiteflies in insect control section of Tomato for more information.

afidopyropen (Sefina): 14 fl oz/A; PHI 0d, REI 12 h, Bee: L, Group 9D.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

Chenopodium extract (Requiem EC): 2 to 3 qts/A; PHI 0d, 4h REI, Bee: L. Apply before pests reach damaging levels.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 10oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, or drip chemigation during first half of crop growing cycle.

dinotefuran (Safari 20SG): 0.16 to 0.32 oz/1,000 sq ft; 3.5 to 7 oz/100 gal; 7 to 14 oz/A; REI 12h, Bee: H, Group 4. Cucumber and melon transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Do not apply to vegetables grown for seed.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

fenpyroximate (Portal XLO): 2 pt/A; PHI 3d, REI 12 hr, Bee: L, Group 21A. A selective contact miticide. Melons only.

flonicamid (Beleaf 50SG): 2.8 dry oz/A; 4.28 oz/A or 0.1 oz/1000 sq ft for greenhouse cucumbers; PHI 0d, REI 12, Bee: L, Group 9C. Suppression only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; 0.44 fl oz/10,000 plants on seedling transplants in greenhouse; PHI 21d, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection. Not for foliar applications.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May require repeated applications. Use of a companion labeled insecticide is recommended for enhanced and residual control.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Knack): 8 to 10 oz/A; PHI 7d, REI 12h, Bee: L, Group 7. Does not control adults. Apply when whiteflies reach economic threshold.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 23. Complete coverage is necessary; an adjuvant may be used to improve coverage and control. Effective against egg and nymphal stages.

thiamethoxam (Actara): 3 to 5.5 oz/A; PHI 0d, REI 12h, Bee: H, Group 4.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107 for information on the use of these herbicides.

carfentrazone (Aim EC): REI 12h, Group 14. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): restricted use. REI 12h, Group 22. Use 2-4 pts/A.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Growing on plastic mulch

Many growers choose to grow cucumber, muskmelon, and/or watermelon on plastic mulch. Herbicides can be applied before laying down plastic to help control weeds that may grow underneath the plastic or in planting holes. Herbicides can also be used between rows of plastic. Some herbicides can not be used under plastic, even if they are registered for use in the crop. Read labels carefully! See notes on specific herbicides in the following section for more information on use and timing.

Labeled for preemergence weed control under plastic:

- bensulide (Prefar)
- halosulfuron (Sanda) (not labeled on muskmelons)

Labeled for preemergence weed control between plastic rows (directed and shielded band app)

- bensulide (Prefar)
- clomazone (Command)
- ethalfluralin (Curbit)
- halosulfuron (Sanda) (not labeled on muskmelons)
- pendamthalin (Prowl) (not labeled for cucumbers)

Labeled for postemergence application between plastic rows

- halosulfuron (Sanda) (not labeled on muskmelons)
- paraquat (Gramoxone SL 2.0)
- clethodim (Select Max)
- sethoxydim (Poast)

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): May be used under plastic. *REI 12h, Group 8.* Apply 5 to 6 qt/A. Can be used as a broadcast treatment (no plastic), between rows of plastic, or under plastic. Preplant incorporate by shallow cultivation (1-2"), or apply preemergence and incorporated thoroughly by irrigation/rainfall within 36 hours of application. Used primarily where grasses are a serious problem. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

clomazone (Command 3ME): *PHI 45d for cucumbers, REI 12h, Group 13.* Can be used as a broadcast treatment (no plastic) or between rows of plastic. Do not use under plastic. Apply after seeding to the soil surface. For cucumbers, apply 0.4 to 1 pt/A. For melons, apply 0.4 to 0.67 pt/A. Use the lower rate on coarse-textured soil and the higher rate on fine-textured soil. Will control annual grasses and many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Combining with Curbit (tank mix or sold as premixed product "Strategy") will also control pigweed species. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for replanting restrictions.

DCPA (Dacthal W75): *REI 12h, Group 3.* Not labeled for cucumber. Preemergence to weeds, but after crop emergence. Apply 6 to 14 lb/A after crop has 4 to 5 true leaves, is well established, and growing conditions are favorable for good growth. If weeds have emerged, crop should be cultivated and weeded prior to application. May also be banded to weed-free soil between rows of plastic mulch.

ethalfluralin (Curbit EC): *REI 24h, Group 3.* Can be used as a broadcast treatment (no plastic) or between rows of plastic. Do not use under plastic. Do not soil incorporate prior to planting. Apply to seeded crop at time of seeding or up to two days after seeding, or apply as a banded spray between rows after crop emergence. A minimum of ½" of irrigation water (within two days after application) or ½" of rainfall (within five days of application) is required for activation. Use 3 to 4.5 pt/A, based on soil texture. See label for rate selection. Use during cold, wet weather can result in crop injury or stunting.

ethalfluralin + clomazone (Strategy): *REI 24h, Group 3 and 13.* Use 2 to 6 pt/A, based on soil texture. See label for rate selection. Can be used as a broadcast treatment (no plastic) or between rows of plastic. Do not use under plastic. Do not soil incorporate prior to planting. Apply to seeded crop at time of seeding or up to two days after seeding, or apply as a banded spray between rows after crop emergence. A minimum of ½" of irrigation water (within two days after application) or ½" of rainfall (within five days of application) is required for activation.

pendimethalin (Prowl H₂O): *REI 24h, PHI 35d, Group 3.* Not labeled for cucumber. Row middles only. Apply up to 2.1 pt/A as a shielded application between rows with 6 inches on either side of row middles (before melon transplanting or before a seeded crop has emerged) or between rows covered with plastic mulch (before holes are punched in plastic for melon planting). Make a second shielded application up to 2.1 pt/A per between rows with a minimum of 6 inches on either side of stem or vines or between plastic mulch before melon vine running. Applications must be at least 21 days. Avoid spray contact with melon foliage or running vines because crop injury will occur. DO NOT apply more than 2.1 pt/A in a single application or more than 4.2 pt/A per acre per season.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.* MASSACHUSETTS AND NEW HAMPSHIRE ONLY. This is a restricted label available only to those Massachusetts and New Hampshire growers who register through the website www.farmassist.com and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

■ Herbicides Used Pre- and/or Postemergence to Weeds

halosulfuron (Sanda): May be used under plastic. *PHI 14d cucumber, PHI 57d watermelon and other melon, REI 12h, Group 2.*

Can cause temporary stunting. Heavy rains following applications will increase the potential for crop injury. Use of organophosphate insecticides can increase crop injury from halosulfuron. See the label for other precautions and a list of weeds controlled. Consider using Sandea as a supplement to Strategy (ethalfluralin + clomazone) in cases where Strategy has not provided sufficient weed control and when a postemergence application is not practical.

For cucumber, cantaloupe, honeydew, and crenshaw melon: Apply 0.5 to 1 oz/A uniformly with ground equipment in a minimum of 15 gal of water per acre. Use the lower rate on lighter textured soils with low organic matter

Preemergence

- **Grown on plastic mulch:** Apply following final bed shaping and just prior to the installation of the plastic mulch. Crop may be seeded into this treated area no sooner than 7 days after application and the installation of the plastic mulch unless local conditions demonstrate safety at an earlier interval.
- **Grown on bare ground:** Preemergence - apply after planting, but prior to soil cracking for direct seeded

crops. Can be used as a pre-transplant application. Crop may be transplanted into this treated area no sooner than 7 days after application unless local conditions demonstrate safety at an earlier interval.

Postemergence (grown on bare ground only)

- Apply Sandea after the crop has reached at least 3 to 5 true leaves but before first female flowers appear. If transplanted crop, apply to transplants that are established and actively growing and in the 3 to 5 true leaf stage or no sooner than 14 days after transplanting unless local conditions demonstrate safety at an earlier interval. May be applied as an over-the-top application, a directed spray application, or with crop shields to minimize contact of the herbicide with the crop.

Postemergence (row middles)

- Apply between rows of direct-seeded or transplanted crop. Avoid contact of the herbicide with the planted crop. If plastic is used on the planted row, adjust equipment to keep the application off the plastic.

For nutsedge control in cucumber: A preemergence application can be followed by a postemergence application. Use a spot treatment method, treating only areas of emerged nutsedge. Application rate should not exceed 1.0 oz/A. Avoid contact of the herbicide with the planted crop. It may be necessary to use a second postemergence spot application to areas where the nutsedge has emerged or regrown. For these situations, use a spot treatment method treating only those areas of emerged nutsedge. Do not apply more than 2 applications not to exceed a total of 2 oz/A per 12 month period (including pre- and postemergence), including applications to the crop and to row middle/furrows. Allow a minimum of 21 days between applications.

For watermelon: apply 0.5 to 0.75 oz/A in a minimum of 20 gallons of water per acre. Use the lower rate on lighter textured soils with low organic matter. Where soil is fumigated prior to planting, allow at least five days after soil fumigation before an application of Sandea.

- **Grown on plastic mulch:** Pre-seeding/pre-transplant- Apply following final bed shaping and just prior to the installation of the plastic mulch. Watermelons should be seeded or transplanted into this treated area no sooner than 7 days after the application and the installation of the plastic mulch unless local conditions demonstrate safety at an earlier interval. Use the lower rate on lighter textured soils with low organic matter. Care should be taken to limit movement of herbicide treated surface soil during the transplant process to avoid injury.
- **Grown on bare ground:** For direct seeded crop, apply after planting, but prior to soil cracking. For transplanted crop, watermelons should be transplanted into this treated area no sooner than 7 days after application unless local conditions demonstrate safety at an earlier interval. Care should be taken to limit movement of herbicide treated surface soil during the transplant process to avoid injury.
- **Row Middle Applications:** Apply between rows of direct-seeded or transplanted crop, while avoiding contact of the herbicide with the planted crop. If plastic is used on the planted row, adjust equipment to keep the application off the plastic. Reduce rate and spray volume in proportion

to area actually sprayed. Runners that come in contact with the plastic can pick up residual Sandea and may exhibit a visual crop response. Do not apply more than 2 applications or 1 oz/A of product per 12 month period. (includes applications to the crop and to row middle).

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 14d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 14d (3 day PHI for cucumber and muskmelon), REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

EGGPLANT

Eggplant (family *Solanaceae*; *Solanum melongena*) is thought to have originated in Southern to Southeastern Asia. Eggplant is closely related to pepper, tomato, tobacco and potato, and shares diseases with some of these crops. Cultivation methods are similar to those for pepper, but it is more heat tolerant and cold sensitive. Deep, well-drained sandy loam soils are ideal for eggplant. Southern slopes that warm early in the spring may yield better.

Types and Varieties

Eggplants come in a diverse array of shapes, colors and sizes, and preferences vary widely among markets. The most common type is large, oblong, and deep purple with a green calyx. Asian types are long and slender, often deep purple with purple calyxes. Specialty varieties include finger-sized eggplants, small round eggplants, and different colors in all shapes and sizes.

Eggplant Varieties	
Oblong Large-Fruited	Slender Long Asian
Beatrice	Orient Express
Black Bell	Millionaire
Black Beauty	Slender Finger
Classic	Diamond
Dusky	Hansel
Falcon	Gretel (white)
Nadia	Fairy Tale (striped)
Traviata	
Nubia (striped)	
White Lightning (white)	
Clara (white)	
Dancer (pink)	

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8.

Use a liquid starter fertilizer at transplanting, especially with cool soil conditions. Use a high phosphorus starter fertilizer mixed according to label directions (typically 3 lb/50 gal of water). Apply 8 fl oz (1 cup) per transplant. If plants are to be grown on plastic mulch, the amount of nitrogen fertilizer to be sidedressed can be reduced, since leaching is minimized. Nitrogen can be applied through drip/trickle or overhead irrigation. Drip fertigation is especially advantageous with plastic mulch. Too much nitrogen fertilization will lead to plants that are bushy, leafy and slow to bear fruit. See Plastic Mulch and Row Covers, page 31, and High Tunnels, page 33, for more information.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Eggplant is normally grown from transplants. Between 2 and 4 ounces of seed are required to produce plants for 1 acre. Germinate seeds in flats at 70-75°F. Move to 50-cell trays after emergence. Sowing directly into 50-cell trays will shorten the time needed to produce transplants by approximately 1 week. Good transplants are 6-8 weeks old,

fairly large and slightly hardened. Transplant in the field with 18" (small plant types) to 30" (large plant types) between plants. This requires from 66 to 40 plants per 100' of row respectively. Allow 36-42" between rows. Eggplants are much less cold hardy than tomatoes. Plant eggplants out after overnight low temperatures are consistently above 50°F.

Field Culture

The use of black plastic mulch will usually result in increased early growth and yield with less damage from *Verticillium* wilt, perhaps because of a healthier, more vigorous plant at the time of infection. Eggplant benefits from irrigation during the period of flowering and fruit set. If soil moisture is limited at this time, yields will be reduced. Large plants may benefit from being staked. Use one 4.5' stake per plant. Temperatures above 90°F, and night temperatures below 60°F or above 70°F, can cause poor flowering and flowers drop. Fruit are also vulnerable to sunburn so enough leaf coverage is critical.

Harvest and Storage

Fruit should be harvested by clipping them off with sharp shears when the outside color is a glossy purple, the fruit is firm and before the seed changes color. Soft fruit, loss of glossy color and dark colored seed are signs of over-maturity. Harvest fruit as they mature to ensure continued fruit set. Fruit can be stored up to 10 days at 50-55°F and 90%-95% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Anthracnose (*Colletotrichum coccodes*)

Start with certified, disease-free seed, fungicide treated seed, or treat seed with hot water to disinfest. Rotate with non-solanaceous crops for at least 3 years to allow infested crop residues to decompose completely. Keep fields free of solanaceous weeds and volunteers.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not apply more than 1 application or other Group 11 fungicides before alteration with a non-Group 11 fungicide.

Plant Nutrient Recommendation According to Soil Test Results for Eggplant

EGGPLANT	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O ₅ per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	50	150	100	25-50	0	150	100	50	0
Sidedress 3-4 Weeks after Planting	30-50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	80-100	150	100	25-50	0	150	100	50	0

azoxystrobin plus difenoconazole (Quadris Top): 8.0 to 14.0 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 1.5 pt/A; PHI 3d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

flutriafol (Rhyme): 7 fl oz/A; PHI 0d, REI 12h, Group 11.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

pyraclostrobin (Cabrio EG): 8 to 12 oz/A; PHI 0d, REI 12h, Group 11. Do not apply more than 1 application or other Group 11 fungicides before alteration with a non-Group 11 fungicide.

tetraconazole (Mettle 125ME): 6.0 to 8.0 fl oz/A; PHI 0, REI 12, Group 3. Apply no more than twice before alternating to a fungicide with a different MOA (Group #).

trifloxystrobin (Flint Extra): 3 to 4 oz/A; PHI 3d, REI 12h, Group 11. Do not apply more than 1 application or other Group 11 fungicides before alteration with a non-Group 11 fungicide.

■ Damping-Off

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

thiram (Thiram 42 S): 8 lb/100 lb seed; REI 24h, Group M3.

■ Phytophthora Crown and Fruit Rot (*Phytophthora capsici*)

Phytophthora capsici cannot be managed by fungicide applications alone; successful disease control is achieved only by a season-long effort to manage water and other cultural practices. The single most effective way to control this disease is to prevent its movement into clean fields by equipment, humans, or infested water. Plant susceptible crops (tomatoes, peppers, eggplant, and all cucurbit species) in fields that have no history of this disease and are well-drained. Plant non-vining crops on raised beds, avoid planting in low areas where water puddles, and improve drainage by sub-soiling after heavy rain events. Promptly disk under small areas where the disease appears along with a border of healthy appearing plants. Avoid working in wet fields and compacting the soil.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 4d, REI 12h, Groups 45 and 40.

dimethomorph (Forum): 6.0 fl oz/A; PHI 0d, REI 12h, Group 40. Must be applied in a tank mix with a fungicide with a different mode of action.

fenamidone (Reason 500 SC): 8.2 fl oz/A; PHI 14d, REI 12, Group 11. For suppression only.

fluazinam (Omega 500): 1 to 1.5 pt/A; PHI 30d, REI 12, Group 29. First application can be made as a soil drench at transplanting.

fluopicolide (Presidio): 3 to 4 fl oz/A; PHI 2d, REI 12h, Group 43. Must be applied in a tank mix with a fungicide with a different mode of action.

mefenoxam (Ridomil Gold SL): 1.0 pt/A preplant or at planting; PHI 7d, REI 48h, Group 4. For crown rot phase only. Apply as a drench at planting or as a banded application. Must be moved into soil mechanically or by irrigation. Use as a preventative, will not cure infected plants.

phosphorus acid (Fosphite): 1 to 3 qts/A; PHI 1d, REI 4h, Group 33. Best efficacy when tank mixed with fungicides with a different mode of action.

■ *Verticillium* Wilt

Verticillium species can persist in the soil for many years in the absence of susceptible plants. Follow a 4- to 5-year crop rotation with non-solanaceous crops to reduce inoculum levels in fields. Include grain crops in the rotation. Control weeds as many weeds are susceptible to *Verticillium*. Remove and destroy infected plant material after harvest. Resistance to *Verticillium* species in pepper and eggplant is poor. Fumigate in fall with Vapam as directed on the label. Mulching plants with black plastic may reduce disease severity. See Soil Fumigation Outdoors, page 89.

Trichoderma asperellum, *T. gamsii* (Bio-tam^{OG}): See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Floating row covers can exclude beetles, increase yield and produce earlier harvests. Plants should be free of aphids and whiteflies before setting in the field. Apply covers immediately after setting transplants. Completely seal edge of the material with soil, leaving enough slack to allow for plant growth. Use wire hoops to prevent damage to growing tips. Use in conjunction with crop rotation to prevent Colorado potato beetles from emerging underneath. Remove row covers at bloom to prevent plants from becoming leggy and lodging. See Plastic Mulch and Row Covers, page 31, and High Tunnels, page 33, for more information.

■ Aphids, Green Peach (*Myzus persicae*) and Melon (*Aphis gossypii*)

See melon aphid in the insect control section of Cucumber and green peach aphid (GPA) in the insect control section of Pepper for more information on each of these aphid species.

Aphids generally colonize eggplant during the first 2 weeks of July, and good control at this time with a selective insecticide will prevent the need for sprays later in the season. Good coverage of the underside of leaves is important. Treat when 1 to 2 aphids per leaf are observed. Be aware that broad-spectrum insecticide applications can cause aphid and mite outbreaks by reducing the populations of beneficial organisms.

Reflective mulch, where 50% of the surface area is reflective, will repel colonizing aphids. Even black plastic mulch has been shown to reduce aphid infestations to some extent compared with bare-ground culture.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 3 fl oz/A; PHI 0d, REI 4 h, Bee: L, Group 9D.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{0G}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{0G}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection. Suppression only.

dinotefuran (Safari 20SG): 0.16 to 0.32 oz/1,000 sq ft; 3.5 to 7 oz/100 gal; 7 to 14 oz/A; REI 12h, Bee: H, Group 4. For transplants while in greenhouse. Not for use on greenhouse or field grown crops.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. For green peach and potato aphids only. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage.

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H,

Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{0G}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with companion labeled aphicide.

methomyl (Lannate LV*): 12 to 48 oz/A; PHI 5d, REI 48h, Bee: H, Group 1A. For green peach aphid.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. For foliar treatment by ground equipment when insects first appear.

petroleum oil (Suffoil X^{0G}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9B. Green peach and potato aphids only. Translaminar. Apply when aphids first appear, before populations build up.

pyrethrin (PyGanic EC5.0^{0G}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 1d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflo (Closer SC): 1.5 to 2 oz/A; PHI 1d, REI 12h, Bee: H, Group 4C. Do not apply until after petal fall.

thiamethoxam (Actara): 2 to 3 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations. DO NOT apply as a foliar spray.

tolfenpyrad (Torac): 17 to 21 fl oz/A; PHI 1d, REI 12 h, Bee: H, Group 21A.

■ Blister Beetles (*Epicauta funebris* and *E. vittata*)

See Blister Beetles in the Beets and Swiss chard section for more information on these two species of blister beetles. Note that both species feed on flowers and foliage in eggplant. A single spot spray with a broad-spectrum insecticide that is registered for blister beetles or flea beetles on this crop will control blister beetles.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

petroleum oil (Suffoil X^{0G}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

■ Colorado Potato Beetle (*Leptinotarsa decemlineata*)

See Potato for more details on Colorado potato beetle (CPB), including cultural controls and resistance management. In eggplant, CPB feeding may occur in June on young transplants, or later in the season when plants are full grown and fruit is developing. Watch for emergence of summer adults in late July and August, as they can damage leaves, flowers, petioles, including clipping flower buds. This reduces fruit formation and marketable yield. Scout to determine number of adults, egg masses, small and large larvae and to assess feeding damage. The following action thresholds have been established from seedling to fruiting stage: 2 small larvae or 1 large larva per plant (if plant is 6 inches). Avoid using insecticides from the same resistance group more than once per year.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

acetamiprid (Assail 30SG): 1.5 to 2.5 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A.*

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.*

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A.*

***Bacillus thuringiensis* subsp. *tenebrionis* strain SA-10 (Trident^{OG}):** 3 to 6 qt/A; *PHI 0d, REI 4h, Bees: M, Group 11.* Only use 3 qt/A rate when light populations of larvae of uniform age or size are present. Use of an adjuvant may improve efficacy, but avoid mixing with silicone-based surfactants. Do not apply while pollinators are actively visiting the treatment area.

***Beauveria bassiana* (Mycotrol ESO):** 0.5 qt to 1 qt/A; *PHI 0d, REI 4h, Bee: L, Group 22.* Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; *PHI 1d, REI 4h, Bee: L, Group 28.* May be applied through drip irrigation or as a foliar spray. For soil applications, must be applied uniformly in the root zone; for foliar applications may be combined with a labeled adjuvant for improved leaf adhesion or control in dense foliage.

cyantraniliprole (Exirel): 7 to 13.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.*

cyantraniliprole (Verimark): 5 to 10 oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.* For drip chemigation, or soil injection applications.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; *PHI 21d, REI 24, Bee: H, Group 3.* Do not apply during bloom or if bees are actively foraging.

flupyradifurone (Sivanto): 10.5 to 14 oz/A; *PHI 1d, REI 4h, Bee: L, Group 4D.* Foliar applications only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar; *PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A.*

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

novaluron (Rimon 0.83EC): 9 to 12 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16B.*

oxamyl (Vydate* L): 2 to 4 pt/A; *PHI 1d, REI 48h, Bee: H, Group 1A.* For foliar treatment by ground equipment when insects first appear.

permethrin (Pounce* 25WP): 9.6 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.*

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

spinetoram (Radiant SC): 5 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.*

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Do not apply Group 5 insecticides to consecutive generations of CPB, and do not make more than 2 applications to a single generation.

thiamethoxam (Actara): 2 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

tolfenpyrad (Torac): 14 to 21 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A.*

■ Cutworms

Black cutworm is the most common of the many cutworm species that damage eggplants in New England. The dark-grey or black caterpillars hide under the soil surface adjacent to the plant stem during the day and feed after dark. On rare occasions, large larvae switch from leaf feeding to cutting stems of seedlings. Certain fields tend to have a history of repeated cutworm damage. Scout fields weekly through June after transplanting. Check at least 100 plants for cut stems, especially near field margins. Spot spray damaged areas or edges of the field if 1% or 2% of the plants have been cut down. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Hardening seedlings before transplanting toughens stems and reduces damage. See cutworms in the Pepper section for more information on this pest.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M.*

carbaryl (10% Sevin Granules): 20 lb/A; *PHI 3d, REI 12h, Bee: H, Group 1A.* Apply evenly to the soil surface.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A Danitol 2.4EC + 0.25 to 2 lb/A DiPel DF; *PHI 3d, REI 24, Bee: H, Group 3.* Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 0.9 to 1.6 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft; *PHI 1d, REI 4h, Bee: M, Group 5.* Spread bait on soil around plants.

tebufenozide (Confirm 2F): 6 to 16 oz/A; *PHI 7d, REI 4h, Bee: L, Group 18.* Must be ingested. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations. Use of a spreader-binder adjuvant is recommended.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Flea Beetle, Potato (*Epitrix cucumeris*)

Potato flea beetle feeds primarily on solanaceous crops (eggplant, tomato, pepper and potato), solanaceous weeds (jimsonweed, ground cherry, black nightshade), and other weeds including redroot pigweed and lambsquarters. It does not feed in brassica crops. Adults are 1.5 to 2.0 mm, dull

black, short and broad, with a pitted and hairy body. Adult beetles spend the winter protected under leaf litter in field edges near the crop where they were feeding in late summer, and search out weed and crop plants in the spring. Eggs are laid in the soil, larvae feed on roots, and after a pupal stage in the soil, a new generation of adult beetles will emerge. These 'summer adults' feed heavily and then move to a protected spot for the winter. Thus, there are 2 major flushes of adults—one in late May and early June, and the second from mid-July to mid-August. Leaves that are heavily damaged may be riddled with small round 'shot holes' that stunt or kill plants. Potatoes, once well established, can withstand considerable feeding damage. Eggplants are vulnerable even at later stages, especially when summer adults emerge and fruit is forming.

Management practices include clean cultivation, crop rotation, removing or avoiding spring weed hosts, using row covers, and applying spot treatments targeting eggplants along the field edges. Scout to observe beetles and damage. Treat newly set transplants if they have 2 flea beetles per plant, seedlings 3" to 6" tall if they have greater than 4 beetles per plant, and plants over 6" tall if they have 8 beetles per plant. Most insecticides registered to control CPB, including spinosad, will control FB. Systemics applied to the soil at transplanting may control both flea beetle and Colorado potato beetle; avoid using the same chemical group for both soil and foliar treatments.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A.*

beta-cyfluthrin (Baythroid* XL): 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; *PHI 3d, REI 12h, Bee: H, Group 1A.*

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.* For soil applications at planting.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; *PHI 21d, REI 24, Bee: H, Group 3.* Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; *PHI 21d, REI 12h, Bee: H, Group 4A*. Only soil applications allowed for flea beetle control.

kaolin (Surround WP^{OG}): 12.5 to 50 lb/A or 0.125 to 0.5 lb/gal; *PHI 0d, REI 4h, Bee: L*. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 25% of its expected harvest size. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*.

permethrin (Pounce* 25WP): 6.4 to 9.6 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A*.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A*.

spinosad (Entrust SC^{OG}): 4 to 8 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5*. Suppression only. Do not apply to seedlings for transplant.

thiamethoxam (Actara): 2 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4*.

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4*. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations.

tolfenpyrad (Torac): 17 to 21 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A*.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

■ Pepper Maggot (*Zonosemata electa*)

Some farms with high population of pepper maggot experience damage on eggplant, especially when peppers are rotated out of the field. Perimeter trap cropping can help limit damage to eggplant. Plant 1 or 2 rows of cherry peppers around the perimeter of the eggplant and spot spray the trap crop (only) when the first stings (egg-laying scars) occur on the peppers or adult flies are captured on traps. See pepper maggot in Pepper section for more details and for effective insecticides for peppers.

■ Potato Leafhopper (*Empoasca fabae*)

Potato leafhopper feeding is toxic to eggplant. Leaf margins and tips turn yellow and curl up. Feeding can reduce yield before damage is visible. Damage is often confused with Verticillium wilt, where leaves turn yellow and droop down. Treatment is recommended if there is an average of more than 1 to 1.5 leafhoppers per leaf. See potato leafhopper in the Potato section for more information.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A*.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A*.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28*.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; *PHI 3d, REI 12h, Bee: H, Group 1A*.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4*. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A. Can be combined with Belay, but this combination should not be applied during bloom or if bees are actively foraging; *PHI 3d Danitol alone, PHI 21d Danitol + Belay, REI 24h, Bee: H, Group 3*.

flupyradifurone (Sivanto): 7 to 10.5 oz/A foliar, 21 to 28 oz/A soil; *PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D*.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar; *PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A*.

kaolin (Surround WP^{OG}): 12.5 to 50 lb/A or 0.125 to 0.5 lb/gal; *PHI 0d, REI 4h, Bee: L*. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 25% of its expected harvest size. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A*.

thiamethoxam (Actara): 2 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A*.

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4A*. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

■ Stink Bugs

See Tomato section for information on stink bugs, including brown marmorated stink bug.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Use higher rate for control of Brown Marmorated Stink Bug.

dinotefuran (Venom): 1 to 4 oz/A; PHI 1d, REI 12h, Bee: H, Group 4A. Foliar applications only. For brown, consperse, green, and Southern green stink bugs only. Coverage is essential for adequate control.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A. Can be combined with Belay to control brown stink bugs only, but this combination should not be applied during bloom or if bees are actively foraging; PHI 3d Danitol alone, PHI 21d Danitol + Belay, REI 24, Bee: H, Group 3.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

novaluron (Rimon 0.83EC): 12 oz/A; PHI 1d, REI 12h, Bee: L, Group 16B.

■ Tarnished Plant Bug (*Lygus lineolaris*)

See Lettuce for information about tarnished plant bug.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 2.1 to 2.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sulfoxaflor (Closer SC): 2.75 to 4.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 4C. Do not apply until after petal fall.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Tomato Fruitworm (*Helicoverpa zea*)

This is another common name for the corn earworm. Caterpillars may attack tomatoes and other solanaceous crops late in the season, especially if moth numbers are high and fresh corn silk is relatively scarce. Use selective insecticides to avoid disrupting natural enemies that control secondary pests, such as mites and aphids. For more information, see corn earworm in the Sweet Corn section.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone; for foliar applications may be combined with a labeled adjuvant for improved leaf adhesion or control in dense foliage.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 7 to 13.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Apply when larvae are first observed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A; PHI 3d, REI 24, Bee: H, Group 3. Can be combined with DiPel DF. Control may be improved by the addition of a non-ionic surfactant.

flubendiamide (Belt SC): 1.5 oz/A; PHI 1d, REI 12h, Bee: L, Group 28. Must be ingested, ensure good coverage and apply to coincide with early threshold levels in developing larval population.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 3.5 oz/A; PHI 3d, REI 12h, Bee: H, Group 22.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate LV*): 24 to 48 oz/A; PHI 5d, REI 48h, Bee: H, Group 1A.

methoxyfenozide (Intrepid 2F): 10 to 16 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Suppression only. Apply at first sign of feeding damage, or when threshold levels are reached.

novaluron (Rimon 0.83EC): 9 to 12 oz/A; PHI 1d, REI 12h, Bee: L, Group 16B.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

Two-spotted spider mite (TSSM) is the most common mite species that attacks vegetable crops in New England and feeds on tomato, eggplant, potato, beans, vine crops such as melons and cucumbers, and other crops. In eggplant, TSSM is a key insect pest. Adult females are approximately 1/50" long, slightly orange or pale green in color with 2 dark spots on their body, and lay up to 100 eggs over their 3 to 4-week lifespan. Eggs are globular and amber red when viewed with a 10X hand lens. Eggs hatch in about 3 days and immediately begin feeding. Following two brief nymphal stages, they become adults and start laying eggs in 1 to 3 days. The life cycle can be completed in 7 to 14 days, depending on temperature.

Foliar damage results from piercing plant tissue with their mouth-parts and removing plant fluids. Feeding injury often gives the top leaf surfaces a mottled or speckled, dull or bronzed appearance. Mites cover the leaves with fine webbing. Other symptoms include distorted leaves, stunting and overall loss of plant vigor (in spite of adequate moisture and nutrition), whitening or spotting of leaves, yellowing of the plant or some of the leaves, and in some cases loss of foliage and death. Spider mites are favored and by hot, dry, dusty conditions, which also aggravates injury by stressing the plant, and by excess nitrogen which fosters succulent growth. Damage is often underestimated or goes unnoticed since the wounds and the pest are not easy to see without close inspection.

Overhead irrigation or prolonged periods of rain can help reduce populations. Do not over-fertilize. Avoid weedy fields and do not plant eggplant adjacent to legume forage crops. Avoid planting eggplant near dusty, high-traffic farm roads. Scout by searching leaves for symptoms and webbing, and using a 10x or 15x hand lens to identify mites. Use selective products and avoid broad-spectrum insecticides for this and other pests wherever possible, because outbreaks are often caused by the use of broad-spectrum insecticides that interfere with the numerous natural enemies that help to manage mite populations. With most miticides (except those with a long residual such as bifentazate), use 2 applications, approximately 5 to 7 days apart, to help control immature mites that were in the egg stage and protected during the first application. Alternate between products after 2 applications to help prevent or delay resistance. Preventative releases of the predatory mite, *Phytoseiulus persimilis*, may suppress TSSM populations, as they do in strawberry fields. Releases must be made when

TSSM numbers are low. *Amblyseius fallicis* is a predatory mite that is widely used in greenhouses. See Vegetable Transplant section on insect and mite management and on scouting guidelines and biological control for information.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

acequinocyl (Kanemite 15SC): 31 oz/A; PHI 1d, REI 12h, Bee: L, Group 20B. Do not use less than 100 gal water/A. Use of an adjuvant or surfactant is prohibited.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; PHI 3d, REI 12h, Bee: L, Group 25. Long residual; not systemic, ensure complete coverage of upper and lower leaf surfaces and fruit.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

etoxazole (Zeal): 2 to 3 oz/A; PHI 7d, REI 12h, Bee: L, Group 10B. Do not apply more than once per season.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A; PHI 21d, REI 24, Bee: H, Group 3.

fenpyroximate (Portal XLO): 2 pt/A; PHI 1d, REI 12hr, Bee: L, Group 21A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

insecticidal soap (M-Pede^{OG}): 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

neem oil (Trilogy^{OG}): 0.5 to 2% solution in 25 to 100 gal water/A; PHI 0d, REI 4h, Bee: M, Group 18. Avoid mid-day applications and ensure good coverage.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. For foliar treatment by ground equipment when insects first appear.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

soybean oil (Golden Pest Spray Oil^{OG}): 2 gal/10 to 80 gal water/A; REI 4h, Bee: L, Group 25. Apply once a week beginning when mites first appear.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 1d, REI 12h, Bee: M, Group 23. Effective on all developmental stages, but juvenile stages more susceptible than adults.

tolfenpyrad (Torac): 14 to 21 fl oz/A; PHI 1d, REI 12h, Bee: H, Group 21A.

■ Whiteflies, greenhouse (*Trialeurodes vaporariorum*) and sweet potato (*Bemisia tabaci*)

Transplant clean plants to the field. Because whiteflies can go from egg to adult in a few days, it is important to make 2 to 3 applications 4 to 5 days apart. Alternate chemical groups to prevent development of resistance. See whiteflies in the Outdoor Tomato section for more information.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 12 fl oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

beta-cyfluthrin (Baythroid* XL): 2.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. For suppression of adults only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

Chenopodium extract (Requiem EC): 2 to 3 qts/A; PHI 0d, 4h REI, Bee: L. Apply before pests reach damaging levels. For silverleaf whitefly.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Suppression only.

dinotefuran (Safari 20SG): 0.16 to 0.32 oz/1,000 sq ft; 3.5 to 7 oz/100 gal; 7 to 14 oz/A; REI 12h, Bee: H, Group 4. For transplants while in greenhouse. Not for use on greenhouse or field grown crops.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Whiteflies only. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage. For greenhouse whitefly suppression only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with a companion labeled insecticide.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9A. Suppression only. Apply when whiteflies first appear.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Knack): 6 to 10 oz/A; PHI 1d, REI 12h, Bee: L, Group 7. Does not control adults. Translaminar.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 1d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 4.25 to 4.5 oz/A. Do not apply until after petal fall; PHI 1d, REI 12h, Bee: H, Group 4C.

thiamethoxam (Actara): 3.0 to 5.5 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used in an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 1d, REI 12h, Bee: M, Group 23. Most effective on immature stages.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): restricted use. REI 12h, Group 22. Use 2-4 pts/A.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): REI 12h, Group 8. Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours or application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions. Can be used under plastic mulches.

DCPA (Dacthal 75WP): REI 12h, Group 3. Crop should be well established before use. Apply 4-6 weeks after

transplanting or on direct seeded plants at 4-6 inches in height. Will not control emerged weeds. If weeds have emerged, the crop should be cultivated or weeded prior to application. Apply 6 to 14 lb/A. See label to select rate based on target weeds and soil texture.

napropamide (Devrinol 2-XT): REI 12h, Group 15. Apply 2 to 4 qt/A before transplanting, to weed-free soil surface. May be applied to transplanted crop only. Use the lower rate on light soil (coarse-textured - sandy) and the higher rate on heavy soil (fine textured - clay). Incorporate thoroughly with irrigation if adequate rainfall does not occur within 24 hours of application.

pendimethalin (Prowl H₂O): PHI 70d, REI 24h, Group 3. Apply 1 to 3 pt/A, either as preplant incorporated or to the soil surface PRIOR to transplanting. Rate based on soil texture; see label for more information. If applied to the soil surface, excessive treated soil falling into the transplant hole may delay crop growth. Can be used under plastic mulch. Can also be applied as a post-directed spray on the soil at the base of the plant, beneath plants, and between rows. Avoid direct contact with foliage or stems or injury will occur. Apply before weed germination. Emerged weeds will not be controlled.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 20d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

halosulfuron (Sandea): PHI 30d, REI 12h, Group 2. Can be used in row middles/furrows only. For direct seeded and transplants, apply 0.5 to 1 oz/A to the area between rows as a banded shielded application while avoiding contact with the crop. If plastic is used on the planted row, adjust equipment to keep the application off the plastic. Reduce rate and spray volume in proportion to area actually sprayed. It is recommended to add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray) to the spray solution for applications where susceptible weeds are present. Provide both preemergence and postemergence control of many weed species, such as nutsedge and many broadleaf weeds. See the label for other precautions and a list of weeds controlled.

paraquat (Gramoxone SL 2.0*): REI 12h, Group 22. For use between rows after crop establishment. Apply up to 2 pt/A as a directed and shielded spray to emerged weeds between rows when weeds are succulent and weed growth is less than 6".

Maximum 3 applications per year. Use precision directed spray application equipment adjusted to prevent spray contact with crop plants. Crop contact by the spray will cause severe injury or death. Do not exceed 30 psi nozzle pressure or spray under conditions which may cause excessive drift.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 20d, REI 12h, Group 1. Carrots only. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

GARLIC

Garlic (*Allium sativum* L.) is in the onion family. For thousands of years it has been grown for culinary and medicinal uses. Garlic grows in a wide range of conditions; while most production is in mild areas, such as California, some varieties grow well in cold climates, often with better flavor.

Types and Varieties

There are two types of garlic. Hardneck (or topset) garlic produces false flower stalks, called scapes. It typically has a half dozen cloves per bulb, plus or minus. Softneck garlic dominates commodity production but in New England many growers prefer hardneck types for retail sale due to their flavor and appearance, which often includes a reddish purple clove covering versus the white color common to softneck types. Softneck garlic, which has more than twice as many cloves, generally has a longer storage life than hardneck and is easier to braid.

After centuries of cultivation garlic has lost the ability to produce seeds so it is vegetatively propagated by saving bulbs and planting the cloves. The small bulbils produced on hardneck scapes can be used for propagation, but it takes several years of planting and selection to achieve marketable size bulbs.

Although many different variety names are used in garlic commerce, recent genetic research suggests there are only about 10 major varieties of garlic. These express different characteristics from one location to another, complicating variety identification. Since there is no standardization of varieties, as with potatoes, one must take garlic variety names with a grain of salt. It's a good idea to start out with several different varieties produced in your area select and save those that perform best.

Soil Fertility

A well-drained soil with good tilth and plenty of organic matter is ideal for garlic. Excess moisture, compaction or droughty conditions will reduce yields. The optimum soil pH is between 6 and 7. Since garlic commences growth very early in the season it is important to have fertility available at that time. The table below gives timing guidelines for use of quick release sources, especially of nitrogen. Adjust timing if using a slower release material. Also, since garlic has such an early start, avoid fields that are slow to drain in the spring.

Planting

Garlic is planted in the fall since it requires a cold treatment to induce bulb formation. Planting typically occurs from October in northern New England to early November in southern areas. The goal is to allow good development of roots but not enough time for the shoots to emerge from soil before winter. Many different planting arrangements are used by growers depending on their irrigation, mulching and weed control systems. Spacing too close can reduce bulb size while spacing too far apart reduces yield per area of land. Planting arrangements include: 2 row beds 30" apart on center with 6" spacing in and between rows; 3 or 4 rows per bed, with 6-8" between and within rows; single rows spaced 24-30" with 6" spacing in the row. Wide row spacing between rows allows for easy mechanical cultivation for weed control; multiple rows per bed allow for use of plastic mulch to control weeds.

Garlic varieties differ in size and weight of cloves; generally, there are about 50 cloves per pound of cloves. Large cloves tend to produce the most vigorous plants and largest bulbs; therefore, small cloves are often not planted. Bulbs should be separated no more than a day or two before planting so they do not dry out. Cloves should always be planted with the root side down, so the top of the clove is 1" deep. Only healthy-looking cloves should be planted to avoid disease and nematode problems.

Field Culture

A layer of clean straw mulch is typically applied to garlic at planting time to avoid soil temperature fluctuations and heaving in the winter and early spring. The garlic will grow through the mulch in the spring. The mulch also will help conserve soil moisture and suppress weeds. However, it may be advisable to remove mulch in a very wet spring to allow soil to dry out and thus reduce the threat of soil borne diseases. In very cold growing areas, removal of mulch can also speed soil warming and garlic growth in the spring. Because garlic is shallow-rooted, irrigation is very beneficial during dry periods. Removal of scapes from hardneck garlic once they fully emerge is recommended because this will improve bulb size, and there is a good market for them.

Harvest and Storage

Although variable depending on variety and growing conditions, 1 lb of garlic 'seed' bulbs will usually yield between 4 and 8 lb at harvest. Depending on the varieties grown and location, garlic may be ready to harvest over several weeks during July. When the lower third of leaves turn brown, pull some bulbs, cut them across the cloves and look to see if the cloves have filled the skins and are ready to harvest. Pull, dig and/or undercut the bulbs to remove them. Unless a lot of soil is adhered to the bulbs they do not need to be washed at harvest although your markets may demand it. Place the harvested plants on wire racks or tie up in bundles and hang to cure for several weeks in a dry area with good ventilation. Then cut the tops off leaving an inch or so and trim the roots closely. If necessary, bulbs may be brushed or the outer skin gently rubbed off to clean them.

Seed garlic should be stored at 50°F with relative humidity of 65-70%. Cloves sprout most rapidly between 40 and 50°F. Garlic for table stock should be stored at 32° and 65-70% relative humidity. Well cured bulbs in good condition should keep for 6-7 months. Relative humidity in storage is lower than for most vegetables because high humidity causes root growth and mold.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

The most common controls for leek and garlic diseases include the use of disease resistant cultivars and pathogen-free seed and bulbs, and cultural practices such as crop rotation and crop residue management that restrict the pathogens.

■ Blue Mold (*Penicillium species*)

Blue mold is a harvest and storage disease and may be particularly prevalent on fresh garlic. Several *Penicillium* species cause blue mold and these species are common in soil, on plant and animal debris, and in senescing plant tissues. Some species may be borne in infected cloves or seed. Invasion is usually through wounds, mechanical bruises, or freezing injury. Control other diseases in the field to prevent avenues for infection. Harvest bulbs with a minimum of bruising and wounding and dry promptly. Store bulbs at 5°C (40°F) with low relative humidity. Some countries recommend treating with fungicides before storage.

Plant Nutrient Recommendation According to Soil Test Results for Garlic

GARLIC	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O ₅ per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate in fall	40	150	100	25-50	0	150	100	50	0
Sidedress in spring when shoots are 6" high	40	0	0	0	0	0	0	0	0
Sidedress 3-4 weeks later	40	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	120	150	100	25-50	0	150	100	50	0

thiophanate methyl (Topsin M 70WP): 1.0 lb/100 gal; *REI 72h, Group 1*. Pre-plant treatment by immersion of garlic cloves in suspension for at least 5 minutes.

■ **Damping-off and seed rot (*Pythium* and *Rhizoctonia*)**

Avoid excessive soil moisture by improving soil drainage or planting on raised beds. Seed and soil treatments with fungicides are a recommended practice.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lbs seed; *REI 48h, Group 4*. Not effective for *Rhizoctonia*.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; *REI 12h, Group 12*. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

■ **Downy Mildew (*Peronospora destructor*)**

During extended periods of cool, humid weather, this disease can be highly destructive, causing losses in both yield and bulb quality. Practice a 3- to 4-year rotation. Plant on well-drained soil and orient rows in the same direction as prevailing winds. Avoid overhead irrigation. A regular program of fungicide spraying based on climatic conditions and disease forecasts should be followed.

ametocradin plus dimethomorph (Zampro): 14.0 fl oz/A; *PHI 0d, REI 12h, Groups 45 and 40*.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11*. Do not make more than 1 application of Quadris before alternating with fungicides that have a different mode of action.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.6 pt/A; *PHI 14d, REI 12h, Groups 11 & M5*. See label for tank mix precautions.

azoxystrobin plus propiconazole (Quilt Xcel): 17.5 to 21 fl oz/A; *PHI 14d, REI 12h, Group 11 & 3*.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; *PHI 0d, REI 4 h, Group 44*. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; *PHI 0d, REI 48h, Group M1*. Can cause phytotoxicity to leaves.

dimethomorph (Forum): 6.0 fl oz/A; *PHI 0d, REI 12h, Group 40*. Forum must be applied as a tank mix with another fungicide that has a different mode of action. Apply in adequate water.

famoxadone plus cymoxanil (Tanos): 8 oz/A; *PHI 3d, REI 12h, Groups 11 & 27*. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 fl oz/A; *PHI 7d, REI 12h, Group 11*. Do not make more than one application of Reason before alternating to a fungicide from a different resistance management group

fluzinam (Omega 500): 1pt/A; *PHI 7d, REI 12h, Group 29*. Use sufficient water for thorough coverage, but not less than 5 gal./A.

mancozeb (Dithane F45): 2.4 qt/A; *PHI 7d, REI 24h, Group M3*.

mandipropamid (Revus): 8.0 fl oz/A; *PHI 7d, REI 4h, Group 40*.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; *PHI 7d, REI 48h, Groups 4 & M5*.

mefenoxam and mancozeb (Ridomil Gold MZ): 2.5 lbs/A; *PHI 7d, REI 48h, Groups 4 & 18*. Use sufficient water to obtain thorough coverage. Do not apply Ridomil Gold more than 4 times.

oxathiapiprolin & mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; *PHI 7d, REI 4h, Group 49 & 40*.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/in a minimum of 20 gal/A; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that heat or moisture stressed. Do not apply directly to copper treated plants within 20-day interval to avoid plant injury.

pyraclostrobin (Cabrio EG): 12 oz/A; *PHI 7d, REI 12h, Group 11*. Do not rotate with other Group 11 fungicides.

■ ***Fusarium* Basal Plate Rot (*Fusarium* species)**

A basal rot of garlic is caused by *Fusarium culmorum* and *F. roseum*. Symptoms include preemergence decay of cloves and seedlings, decay of the stem plate and storage leaves during the growing season, and postharvest decay of cloves in stored bulbs. Foliar symptoms include curving, yellowing and necrosis of leaves beginning at tips, and wilt. Infection occurs mainly from the soil through the stem plate. Incidence of the disease increases with injury by the onion maggot or other insects. Cloves may remain infected but non-symptomatic. The pathogen is disseminated in seed, soil, infected debris, and irrigation water. Hot water seed treatment has reduced garlic clove infection by 50%, but is not enough to provide commercially acceptable control when clove infection is severe. Long (4 year) rotations to non-susceptible crops may minimize losses. Storage at 4°C also helps. The most important control measure is the planting of resistant cultivars.

■ **Purple Blotch (*Alternaria porri*)**

Practice long rotations with unrelated crops and practices that reduce hours of leaf wetness, i.e., plant spacing and good air drainage. Plant resistant or tolerant varieties. Plow under crop residues promptly after harvest. Rotate fungicides throughout the growing season.

azoxystrobin (Quadris): 6.0 to 12.0 fl oz/A; *PHI 7d, REI 4h, Group 11*. Do not rotate with other Group 11 fungicides.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; *PHI 14d, REI 12h, Groups 11 & M5*. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; *PHI 1d, REI 12h, Groups 11 & 3*.

azoxystrobin plus propiconazole (Quilt): 14 to 27.5 fl oz/A; *PHI 14d, REI 12h, Group 11 & 3*.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; *PHI 0d, REI 4 h, Group 44*. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

boscalid (Endura): 6.8 oz/A; *PHI 7d, REI 12h, Group 7*. Do not make more than 2 consecutive applications before rotating to a fungicide with a different mode of action.

chlorothalonil (Bravo Weather Stik): 1 to 3 pt/A; PHI 7d, REI 12h, Group M5. When disease is present, use the higher rate.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12. Do not make more than 2 consecutive applications before rotating to a fungicide with a different mode of action.

difenoconazole plus cyprodinil (Inspire Super): 16 to 20 fl oz/A; PHI 7d, REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage.

famoxadone plus cymoxanil (Tanos): 8 oz/A; PHI 3d, REI 12h, Groups 11 plus 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 7d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

mancozeb (Dithane F45): 2.4 qt/A; PHI 7d, REI 24h, Group M3.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propiconazole (Tilt): 4 to 8 fl oz/A; PHI 14d, REI 12h, Group 3.

pyraclostrobin (Cabrio EG): 8 to 12 oz/A; PHI 7d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides (Quadris).

pyraclostrobin plus boscalid (Pristine): 10.5 to 18.5 oz/A; PHI 7d, REI 12h, Groups 11 & 7. Do not make more than 2 applications of Pristine before alternating with a fungicide with a different mode of action.

pyrimethanil (Scala SC Fungicide): 18 fl oz/A; PHI 7d, REI 12h, Group 9.

■ Stem and Bulb Nematode-Garlic Bloat (*Ditylenchus dipsaci*)

Ditylenchus dipsaci infects germinating seed or is borne in seed cloves. The nematode can be easily spread in infested soil, on equipment, and in infected seed and plant material. *D. dipsaci* is common in all temperate regions. It is an obligate parasite of plants; populations of the nematode exhibit marked host preferences. The nematodes aggregate into a mass called nematode wool and with slow drying can persist in infested fields for long periods. Symptoms include erratic stands, stunting, looping and bending of leaves, twisting, and growth deformities. Bulb damage can be mistaken for Fusarium basal plate rot with decay occurring both at the neck and the basal plate. *D. dipsaci* can be controlled with long crop rotations including the elimination of volunteer onions, garlic, and host weeds. The primary method of controlling nematodes is hot water treatment of seed cloves. The standard regime is 30 to 45 minutes at 38°C (100°F), 20 minutes at 49°C (120°F), and then 10 to 20 minutes at 18 to 22°C (64 to 72°F). Hot water treatment must be performed carefully to prevent damage to cloves. An alternative is the production of nematode-free seed cloves by meristem culture and isolated production. Chemical, physical,

and cultural methods have been used to restrict damage, but most chemical treatments are no longer registered for use.

■ White Rot (*Sclerotium cepivorum*)

Avoid planting in infested fields. Disease development is favored by cool, moist soil conditions. Warm season production of host crops may greatly reduce sclerotial inoculum. Rotate crops for as many years as possible. Some fungicides (iprodione) provide protection for the establishment of garlic, but fungicide control is marginal for full-season crops. Soil fumigation may provide partial control. In general, neither fungicides nor fumigation have provided consistent, reliable, full-season control of white rot. Hot water treatment of garlic seed can reduce the potential to spread white rot sclerotia. Winter flooding and soil solarization can reduce the number of sclerotia. White rot symptoms are less severe on leeks.

azoxystrobin plus propiconazole (Quilt Xcel): 17.5 to 26 fl oz/A; PHI 14d, REI 12h, Group 11 & 3.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel[®]):** 0.12 to 1.0 lb/A as a soil drench; PHI 0d, REI 4 h, Group 44.

boscalid (Endura): 6.8 oz/A; PHI 7d, REI 12h, Group 7. Apply in-furrow at planting.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

fludioxonil (Cannonball 50WP): 0.5 oz/1000 ft.; PHI 7d, REI 12h, Group 12. Apply in-furrow at planting.

iprodione (Rovral): 4.0 pt/A; REI 24h, Group 2. Apply in-furrow at planting. Do not make more than 1 application per year.

PCNB (Blocker 4F): 5.0 gal/A; REI 12h, Group 14.

tebuconazole (Orius 3.6F): 25 fl oz/A; PHI 7d, REI 12h, Group 3. Apply in-furrow at planting or over the top in a 4 to 6 inch band.

thiophanate methyl (Topsin M 70WP): 2.0 lb/A; REI 72h, Group 1. Apply in furrow.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Bulb Mites

Two genera of mites are known to infect species of Allium. The dry bulb mite (*Aceria tulipae*) is an eriophyid mite that survives on cultivated Allium species. Bulb mite species in

the genus *Rhizoglyphus* can also be troublesome on Alliums. Infected seed may fail to germinate. Plants grown from infected seed may lack vigor and produce stunted, deformed leaves. Plants may outgrow the damage if the infestation is not heavy, but mites may increase in number over the growing season and will remain in the harvested garlic. They are particularly troublesome in storage, causing desiccation and creating wounds that allow for entry of pathogens.

Bulb mites are favored by mechanical injury, disease, cool soil temperatures, and soils with high organic matter content. Avoid adding manure and use fallow periods to eliminate crop residue. In smaller plantings, removing culls from the field immediately after harvest will reduce overwintering populations. Dark plastic mulch will increase soil temperatures and control mites. Plant clean seed and rotate out of Alliums for at least four years after an infestation. Avoid planting Alliums directly after brassicas, corn, grain, or grass cover crops.

■ Onion Maggot (*Delia antiqua*)

For more information on this pest and for cultural and biological controls, see onion maggot in the Onion section.

diazinon (Diazinon* AG500): 2 to 4 qt/A; REI 3d, Bee: H, Group 1B. Broadcast and incorporate just before planting. Will not control organophosphate-resistant onion maggots. DO NOT make more than one application per year.

■ Onion Thrips (*Thrips tabaci*)

Thrips are favored by hot, dry weather. Heavy rain or overhead irrigation can lower populations quickly. Lacewing larvae, pirate bugs and predatory thrips are important natural enemies. Reduce populations by cleaning up crop residue after harvest to limit overwintering sites. Do not plant garlic near other Alliums (onion family) or alfalfa, clover, cucurbits or brassica crops that can harbor large populations of thrips, which may migrate to garlic when these crops are cut or harvested. Begin applications when damage is first noticed. Repeat applications at 7- to 10-day intervals. Use a shorter interval in hot, dry weather. Use spreader-sticker for better coverage. Apply in early evening, using high pressure and 100 gal water/A for best results. See onion thrips in the Onion section for more information.

The most common controls for leek and garlic diseases include the use of disease resistant cultivars and pathogen-free seed and bulbs, and cultural practices such as crop rotation and crop residue management that restrict the pathogens.

acetamiprid (Assail 30 SG): 5 to 8 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

***Beauveria bassiana* (Mycotrol ESO):** 0.25 qt to 1 qt/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M. Suppression only.

***Chenopodium extract* (Requiem EC):** 1.5 to 3 qts/A; PHI 0d, REI 4h, Bee: L. Begin application as soon as thrips are seen. Thoroughly cover foliage.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Suppression only.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 3 to 4 fl oz/A foliar, 5 to 6 fl oz/A soil; PHI 1d foliar, 21d soil, REI 4h, Bee: H, Group 4A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 14d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 14 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression/repellence only. Good coverage into plant crown is essential. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 14d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57 EC): 1.5 to 2 pt/A; PHI 3d, REI 24h, Bee: H, Group 1B.

permethrin (Pounce* 25WP): 9.6 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spinosad (Entrust SC^{OG}): 4 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Suppression only. Use adjuvant for better control.

spinetoram (Radiant SC): 6 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Thorough coverage is essential. Efficacy improves with the addition of an adjuvant.

spirotetramat (Movento): 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

zeta-cypermethrin (Mustang*): 3.2 to 4.3 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): restricted use. REI 12h, Group 22. Use 2-4 pts/A.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

Garlic is not very competitive, so good weed control is critical. Mulch will control weeds and conserve moisture. If the mulch is removed, cultivation will likely be needed. It should be shallow so as not to damage roots.

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): REI 12h, Group 8. Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours of application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

dimethenamid (Outlook): PHI 30d, REI 12h, Group 15. This herbicide is a root and shoot growth inhibitor that controls susceptible germinating seedlings before or soon after they emerge from the soil. Do not apply until garlic has reached the 2 true-leaf stage or significant crop injury can occur. May be applied as a single application (up to 21 oz/A) or used in split applications. For split applications do not exceed a total of 21 oz/A per season. An initial application of 10 to 14 oz/A can be followed by another application of the remaining 7 to 11 oz/A. Applications must be a minimum of 14 days apart. Application rates are influenced by soil organic matter content. See label for info on application rates depending on soil type and organic matter content. See label for info on tank mixing with other herbicides.

flumioxazin (Chateau SW): REI 12h, Group 14. Apply up to 6 oz/A with 3 days of planting garlic and before garlic has emerged. Must be sprinkler or rainfall incorporated (0.5-0.75" of water) for preemergence weed control. Will control many broadleaf weeds and some grass species.

s-metolachlor (Dual Magnum): REI 12h, Group 15. MASSACHUSETTS AND NEW HAMPSHIRE ONLY. This is a restricted label available only to those Massachusetts and New Hampshire growers who register through the website www.farmassist.com and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

pendimethalin (Prowl H₂O): PHI 45d, 24 hr REI, Group 3. Apply 1.5 to 3.2 pt/A. Select rate based on soil texture. See label for detail. Can be used preemergence after planting but before crop emergence, after crop emergence when garlic is in the 1 to 5 true leaf stage, or at both timings. Emerged weeds will not be controlled.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For

best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 45d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluazifop (Fusilade DX): PHI 45d, REI 12h, Group 1. For grass weed control only. Apply 6 to 16 oz/A. See label to select rate based on grasses targeted for control. Allow for minimum 14-days between applications, and not to exceed 48 oz/A per year. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

oxyfluorfen (Goal 2 XL): PHI 60d, REI 48h, Group 1. Provides early postemergence and residual control of many broadleaf weed species. For direct seeded garlic, apply 2 to 4 oz/A to garlic that has at least 3 fully developed true leaves. For transplanted garlic, apply 2 to 4 oz/A to garlic transplants as soon as possible after transplanting. Multiple treatments may be applied up to a maximum of 32 fl oz per acre pre-season. For optimum postemergence control, apply when susceptible weeds are in the 2 to 4 leaf stage and actively growing. Application to weeds at later than 4 leaf growth stage may result in reduced weed control. Adjust nozzles for minimum spray contact with garlic plants, directing the spray to the soil at the base of garlic plants and adjacent bed top and furrow area. Do not tank mix or add adjuvants unless directed to do so on Dow supplemental labeling.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

GLOBE ARTICHOKE

Globe Artichoke (family *Asteraceae*, *Cynara cardunculus* var. *scopolymus*) is the large harvested flower bud of a thistle of Mediterranean origin. The edible portions include both the fleshy bases of the bracts that surround the bud as well as the tender core (heart) that supports the immature florets in the center of the bud. If buds are not harvested and are allowed to flower, the blue/lavender blossoms make excellent bee forage or additions to floral bouquets. Artichoke is closely related to cardoon (*C. cardunculus*) which is grown primarily for its fleshy stems and often eaten braised or fried.

Types and Varieties

In mild climates where temperatures do not remain below 50°F for prolonged periods, globe artichoke is a perennial crop that is propagated vegetatively. Breeding efforts have produced annual cultivars that reliably flower in the first year after a vernalization period of exposure to cool temperatures (35°-50°F) for 8-10 days in the spring. These varieties have performed well in New England.

GLOBE ARTICHOKE VARIETIES
Imperial Star
Emerald

Soil Fertility

Apply lime according to test to maintain soil pH between 6.5 and 7.0. Artichokes can be grown on a wide range of soils but produce best on deep, fertile, well-drained soils. Lighter soils having poor moisture holding capacity should be avoided. Artichokes are moderately salt tolerant.

Planting

Artichokes should be seeded 8-12 weeks before setting transplants outdoors. Seeds take 8-12 days to emerge. Transplants should have at least 4 leaves in 4" pots. Space plants 2-3' apart in rows 4-5' apart. Germination may be improved by soaking seeds for 48 hrs and germinating at 70-80°F. Plants require a chilling period (vernalization) to induce flowering. The amount of chilling required varies with variety. Imperial Star needs approximately 250 hours (ten days) between 35 and 50°F. The easiest way to accomplish this is to time transplanting so that young transplants receive this exposure outdoors, covering plants if frost is expected. For late transplanting dates, plants may need to be artificially vernalized.

Field Culture

If somewhat complicated to start, this crop is mostly trouble free in the field with few pests, and offers New England

customers a fresh Mediterranean treat. In the field, globe artichoke requires a bit of space; 2-3' apart in rows, 4-6' apart. Research in New Jersey showed that using black plastic mulch reduced yields, possibly because higher root zone temperatures can reverse the effects of vernalization. Straw or reflective silver mulch are good alternatives to keep soil temperatures cooler. Plants should begin budding in late July. Pinching off some of the smaller buds can encourage the larger ones to size up. At the end of the season the healthiest artichoke plants with several side shoots can be split and planted into unheated high tunnels under row cover for an early June harvest the following year. Supplemental irrigation may be required in field and tunnel crops as stressed plants produce loose buds that are more susceptible to "black tip", a physiological disorder that causes bracts to become dark brown, making them unmarketable. Plants should receive one inch of water per week to avoid this.

Perennial artichokes have been successfully overwintered in experimental settings (see Northeast SARE project FNE 14-809) in northern New England with a combination of straw mulch and low tunnels; it is possible that refinement of this system could result in earlier harvests and higher yields.

Harvest and Storage

Yields vary, but 2-3 primary buds per plant are average, with 8-10 secondary smaller buds per plant possible. Artichokes are marketed in 22 lb cartons. Marketable buds are graded in the following classes: 18's are larger than 4.5" in diameter; 24's are 4-4.5"; 36's are 3.5-4" and 48's are 3-3.5". Average diameters in New England tend to fall between 3-4". These smaller buds are popular in France as they are tender and sweet when roasted. Buds are harvested with 2-3 inches of stem attached when they have reached their maximum size, but before the lower bracts begin to spread apart or toughen. Overmature buds can become bitter and tough. After harvest, buds should be cooled quickly and stored at temperatures close to 32°F, but should not be allowed to freeze.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Herbicides Used for Pre- and Postemergence Weed Control

oxyfluorfen (Goal 2 XL): PHI 5d, REI 48h, Group 1. Used for both pre- and postemergence weed control. Apply 4 to

Plant Nutrient Recommendation According to Soil Test Results for Globe Artichoke

GLOBE ARTICHOKE	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate in fall	100	75	50	0-25	0	150	100	50	0
Sidedress 3-4 Weeks later	0-50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	120	75	50	0-25	0	150	100	50	0

6 pt/A as a directed spray to the soil surface between the rows and at the base of artichoke plants. Do not apply over-the-top. Contact with direct spray or drift will cause injury to artichoke fronds or severe injury to buds or flowers. Do not apply more than 6 pints of Goal 2XL per acre per season as a result of a single application or multiple applications.

■ Herbicides Used Postemergence to Weeds

clethodim (Select Max): PHI 5d, REI 24h, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

paraquat (Gramoxone SL 2.0*): REI 12h, Group 22. For use between rows after crop establishment. Apply up to 2.5 to 4 pt/A as a directed and shielded spray to emerged weeds between rows when weeds are succulent and weed growth is less than 6". Maximum 3 applications per year, not to exceed a total of 8 pt/A per season. Use precision directed spray application equipment adjusted to prevent spray contact with crop plants. Crop contact by the spray will cause severe injury or death. Do not exceed 30 psi nozzle pressure or spray under conditions which may cause excessive drift.

sethoxydim (Poast): PHI 7d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

LEEK

Leeks are root vegetables that look quite similar to onions, to which they are related. Their flavor is onion-like but much milder. Unlike onions, leeks don't form much of a bulb on the end of the root. Instead, they remain cylindrical, with perhaps a slight bulge at the end. The leek is a vegetable that belongs, along with onion and garlic, to the genus *Allium*, currently placed in family *Amaryllidaceae*, subfamily *Allioideae*. Historically many scientific names were used for leeks, which are now treated as cultivars of *Allium ampeloprasum*.

Types and Varieties

LEEK VARIETIES	
SUMMER/FALL Belton King Richard (open pollinated) Lincoln (open pollinated) Surfer	FALL/OVER-WINTER Lancelot Lexton Megaton Tadorna
SUMMER Rally Runner	

Soil Fertility

See the Soil Fertility sections for Onions.

Planting

For best results, leek seeds should be sown in the greenhouse about 2.5 months before field setting. About 2-3 lb of seed are needed to raise enough plants to set an acre at average spacing (0.25-0.5 oz per 100 feet of row). Plant seeds no more than 1/2" deep in 288 deep cell trays. Before setting, clip plants to a height of 3" to reduce wind damage in the field. Set plants in the field from late April to late May depending on location and earliness desired. Plants can be set in early July for a late fall harvest, or in milder locations, growers may wish to try overwintering the more cold tolerant leek varieties using straw mulch or row covers. Rows can be from 15" to 30" apart depending on equipment; plants should be about 3"-6" apart (200-400 plants per 100 feet of row).

Field Culture

To develop a long, white stem, leeks can be planted in a trench 3"-4" deep. The trenches are gradually filled as the leeks grow and then soil is hilled around stems to a height of 3"-4". Several hillings may be required per season. Self-blanching varieties are grown without trenching and hilling and require less cleaning.

Harvest and Storage

Leeks can be harvested once the base reaches at least 1" diameter. Soil often clings to freshly harvested leeks. Carefully using a pressure washer or hose nozzle with a strong jet of water may be required to sufficiently clean soil particles from leeks for storage or market. Optimum storage conditions are 32°F with 95-100% relative humidity to prevent wilting. Leeks typically maintain quality in storage for two to three weeks. Under ideal conditions, up to eight weeks is possible. Store separately from ethylene-producing crops.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

The most common controls for leek and garlic diseases include the use of disease resistant cultivars and pathogen-free seed and bulbs, and cultural practices such as crop rotation and crop residue management that restrict the pathogen.

■ Damping-off and seed rot (*Pythium* and *Rhizoctonia*)

Avoid excessive soil moisture by improving soil drainage or planting on raised beds. Seed and soil treatments with fungicides are a recommended practice.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lbs seed; REI 48h, Group 4. Seed treatment.

fludioxonil (Maxim 4FS): 0.08-0.16 fl oz/100 lb seed; REI 12h, Group 12. Does not control *Pythium* and *Phytophthora*.

■ **Downy Mildew (*Peronospora destructor*)**

During extended periods of cool, humid weather, this disease can be highly destructive causing losses in both yield and bulb quality. Practice a 3- to 4-year rotation. Plant on well-drained soil and orient rows in the same direction as prevailing winds. Avoid overhead irrigation. A regular program of fungicide spraying based on climatic conditions and disease forecasts should be followed.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 and 40.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not make more than one application of Quadris before alternating with fungicides that have a different mode of action.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.7 pt/A; PHI 14d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

dimethomorph (Forum): 6 fl oz/A; PHI 0d, REI 12h, Group 40. Forum must be applied as a tank mix with another fungicide with a different mode of action.

famoxadone & cymoxanil (Tanos): 8 oz/A; PHI 3d, REI 12h, Groups 11 plus 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 7d, REI 12h, Group 11. Do not alternate with other Group 11 fungicides.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; PHI 14d, REI 48h, Groups 4 & M5.

pyraclostrobin (Cabrio): 12 oz/A; PHI 7d, REI 12h, Group 11. Do not make more than one application of Cabrio before alternating to a fungicide with a different mode of action. Do not rotate with Quadris or Cabrio.

■ **Purple Blotch (*Alternaria porri*)**

Practice long rotations with unrelated crops and practices that reduce hours of leaf wetness, i.e., plant spacing and good air drainage. Use of a single fungicide throughout the growing season is not recommended.

azoxystrobin (Quadris): 6.0 to 12.0 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; PHI 14d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus propiconazole (Quilt): 14 to 27.5 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

boscalid (Endura): 6.8 oz/A; PHI 7d, REI 12h, Group 7.

chlorothalonil (Bravo Weather Stik): 1.5 to 3 pt/A; PHI 7d, REI 12h, Group M5. When disease is present, use the higher rate.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

famoxadone plus cymoxanil (Tanos): 8 oz/A; PHI 3d, REI 12h, Groups 11 plus 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason SC): 5.5 fl oz/A; PHI 7d, REI 12h, Group 11. Do not alternate with other Group 11 fungicides.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propiconazole (Tilt): 4 to 8 fl oz/A; PHI 0d, REI 12h, Group 3.

pyraclostrobin (Cabrio EG): 8 to 12 oz/A; PHI 7d, REI 12h, Group 11. Do not exceed six applications or 72 oz/A. Do not rotate with other Group 11 fungicides.

pyraclostrobin plus boscalid (Pristine): 10.5 to 18.5 oz/A; PHI 7d, REI 12h, Groups 11 & 7.

pyrimethanil (Scala SC Fungicide): 9 to 18 fl oz/A; PHI 7d, REI 12h, Group 9.

■ **White Rot (*Sclerotium cepivorum*)**

Avoid planting in infested fields. Destroy infected plants and spot treat the soil around the plants with fumigants. Warm season production of host crops may greatly reduce sclerotial inoculum. Practice crop rotation. Soil fumigation may provide partial control. In general, neither fungicides nor fumigation have provided consistent, reliable, full-season control of white rot. Hot water treatment of seed can reduce the potential to spread white rot sclerotia. Winter flooding and soil solarization can reduce the number of sclerotia. White rot symptoms are less severe on leeks.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Onion Maggot (*Delia antiqua*)**

For more information on this pest and for cultural and biological controls, see onion maggot in the Onion section.

diazinon (Diazinon* AG500): 2 to 4 qt/A; REI 3d, Bee: H, Group 1B. Broadcast and incorporate just before planting. Will not control organophosphate-resistant onion maggots. DO NOT make more than one application per year.

■ Onion Thrips (*Thrips tabaci*)

Thrips are favored by hot, dry weather. Heavy rain or overhead irrigation can lower populations quickly. Lacewing larvae, pirate bugs and predatory thrips are important natural enemies. Reduce populations by cleaning up crop residue after harvest to limit overwintering sites. Do not plant leeks near other Alliums (onion family) or alfalfa, clover, cucurbits or brassica crops that can harbor large populations of thrips, which may migrate to leeks when these crops are cut or harvested. Begin applications when damage is first noticed. Repeat applications at 7- to 10-day intervals. Use a shorter interval in hot, dry weather. Use a spreader-sticker for better coverage. Apply in early evening, using high pressure and 100 gal water/A for best results. See onion thrips in the Onion section for more information.

acetamiprid (Assail 30SG): 5 to 8 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

Beauveria bassiana (Mycotrol ESO): 0.25 qt to 1 qt/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OC}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M. Suppression only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OC}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 3 to 4 fl oz/A foliar, 5 to 6 fl oz/A soil; PHI 1d foliar, 21d soil, REI 4h, Bee: H, Group 4A.

imidacloprid (Admire Pro): 14 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{OC}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression/repellence only. Good coverage into plant crown is essential. Generally compatible as a tank mix with other insecticides.

malathion (Malathion 57 EC): 1.5 to 2 pt/A; PHI 3d, REI 24h, Bee: H, Group 1B.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 6 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Thorough coverage is essential. Efficacy improves with the addition of an adjuvant.

spirotetramat (Movento): 5 oz/A; PHI 7d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

zeta-cypermethrin (Mustang*): 3.2 to 4.3 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and

special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

See Soil Fumigation Outdoors, page 89. Proper use of Vapam can provide control of most weed species.

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

pendimethalin (Prowl H₂O): PHI 30d, REI 24h, Group 3. Apply 2 pt/A to the soil surface as preemergence after planting but before crop emergence, or after crop emergence when leeks are at the 2 to 3 true-leaf stage, or at both timings. Emerged weeds will not be controlled. If applied as both pre- and postemergence, applications must be at least 30 days apart. Do not exceed 2 pt/A per application, and do not apply more than 4 pt/A per season.

■ Herbicides Used Postemergence to Weeds

clethodim (Intensity One): PHI 14d, REI 24h, Group 1. Leeks are NOT on the Select Max label, but are on other clethodim product labels (such as Intensity One). Will control grass weeds only. Apply to actively growing grasses. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Intensity One and 0.25% v:v nonionic surfactant (0.33 fl oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

LETTUCE, ENDIVE, AND ESCAROLE

Lettuce (*Lactuca sativa*), endive and escarole (both *Cichorium endivia*) are members of the *Asteraceae* plant family, and all originated in the Mediterranean region. Their closest crop relatives are artichoke, chicory and sunflower.

Lettuce grows best at cool temperatures, making spring and fall the major production seasons in New England. While endive and escarole are also cool-season crops, they are more tolerant of high temperatures than lettuce and therefore make a good substitute for lettuce during the warmer mid-summer weather.

Types and Varieties

There are four common types of lettuce. Crisphead or iceberg is commonly found in produce markets. The leaves are thin and crisp, often with curled or serrated edges, and the head should be firm. Butterhead or bibb lettuce has a loose-leafed head with green or red outer leaves and cream or yellow inner leaves. Butterhead type lettuce requires careful handling as it bruises and tears easily. For this reason, it is best suited to local market sales. Cos or romaine is an upright plant with the smooth outer leaves and green inner leaves whitish green. Some think the leaves are crisper than other heading types. The fourth general type is variously named leaf lettuce, loose leaf or loose head. Lettuce of this type does not form a head and the leaves may be serrated, deeply lobed or crinkled. Leaf lettuce color varies from light green to red to green with red speckles, adding attractive color to the salad or dinner plate.

Endive and chicory encompass many diverse types. Radicchio forms small, tight heads. Escarole and Frisée are types of endive, both of which form loose and leafy heads. Belgian endive is grown in two stages: during spring/summer, the seeds produce large dandelion-like leaves and a large taproot, similar to carrot. In the fall, the taproots are dug, and potted and placed in the dark. The new growth from the roots produces small tight heads called chicons, which are marketed. Italian (or “culinary”) dandelions form long leaves that are usually bunched.

Lettuce, Endive and Escarole Varieties	
Butterhead Lettuce Adriana - LMV, DM Buttercrunch - LMV, DM Skyphos (red)	Crisphead Lettuce Keeper Summertime
Romaine Lettuce Medallion - LMV Green Forest Green Towers Winter Density Cimmaron (red) Rosalita Valley Heart	Leaf Lettuce New Red Fire Red Sails Slobolt - TB Tehama - TB Two Star Envy Vulcan - TB Green Vision Northstar
Endive Green Curled Salad King	Escarole Full Heart
Belgian Endive Totem	
Resistant or tolerant to: DM: Downy Mildew; LMV: Lettuce Mosaic Virus; TB: Tipburn	

Soil Fertility

Generally lettuce, endive and escarole have the same fertility, spacing and seeding requirements. Apply lime according to soil test results to maintain soil pH at 6.5 to 6.8 and maintain soil calcium levels. Low soil calcium levels may affect the incidence of tip burn. Tipburn is a disorder that causes the margins of leaves to turn black and decay. It is of particular concern with iceberg or romaine types where tipburn on internal leaves may not be immediately obvious. Over-application of nitrogen on fertile soil can result in very rapid growth which can trigger tipburn. Banding the preplant fertilizer at planting is preferable, but if not possible, then broadcast and incorporate the initial application. Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Final spacing on crisphead lettuce, endive, and escarole should be 12"-18" between plants (67-100 plants per 100 feet of row) and 12"-24" between rows. Other types of lettuce can be 10"-16" apart (75-120 plants per 100 feet of row) in 10"-18" rows. Spacings should allow good air movement around the plants to minimize grey mold (*Botrytis*), bottom rot (*Rhizoctonia*), and drop (*Sclerotinia*). Many growers raise lettuce, endive and escarole on 4' wide, raised, 4" high beds with 3-4 rows per bed. This enhances air movement and drier soil conditions for disease control. Growers are also urged to rotate lettuce wherever possible to reduce problems with drop and corky root rot, which can be common when double cropping in the same field. For direct seeding, 10-18 oz of seed are needed per acre (0.0625-0.125 oz per 100 feet of row).

Lettuce will germinate at soil temperatures of 32°F, but the optimum and maximum soil temperature is 75°F. When seeded at a soil temperature of 80°F, the seed will not germinate but rather remain dormant until the temperature lowers. Lettuce that is already established and subjected to high temperatures will bolt and form a seed head. Generally lettuce, endive and escarole have the same spacing, seeding and fertility requirements. For once-over harvesting, uniformity at harvest is essential. Producers for direct retail markets and CSA might prefer variable maturity. Precision seeding with modern planters and coated seed can enhance uniformity. Irrigation immediately after seeding also promotes uniform emergence.

Since lettuce matures quickly (40-50 days), and temperature affects days to harvest, plant several successions to get consistent production into the summer.

Transplants are often used for lettuce production and can be used all season, from mid-April to August 1. Some growers use floating row covers over beds with early transplants for earlier crops. Hardened transplants should be set out when they are 3- to 4-weeks old. Hardening is accomplished by withholding water and gradually reducing temperatures for 10 days before the planned transplant date. Use of a liquid starter fertilizer at transplanting time can reduce shock and provide immediately available nitrogen and phosphorus in cold soil. Use a dilute solution to avoid injury to roots. Varieties that do well as transplants even in mid-summer and are very slow to bolt include Adriana (Boston), Slobolt (green leaf), New Red Fire (red leaf), and Green Forest (Romaine). In hot summer conditions, starting transplants in the greenhouse or shade house provides better germination than in the field.

Field Culture

Many growers that use polyethylene mulches for water conservation and weed control prefer to use plastic that is white above and black below (white on black) for growing lettuce and other cool season vegetables. It can cool soil temperature by up to a few degrees in high temperature conditions and can reduce the tendency of lettuces to bolt.

Harvest and Storage

Food safety issues from microbial contamination are often linked to leafy greens that are eaten raw. It is important to follow some basic practices that are in accord with the guidance outlined in the Food Safety section of this guide. In general, lettuce, escarole and endive are fragile. Heading lettuces, endive and escarole are more easily stored than leaf lettuces. Low temperatures and high relative humidity are needed to prevent wilting. These crops are damaged by freezing temperatures (32°F), but should be cooled as quickly as possible and maintained as close to 32°F as possible with 98-100% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Bottom Rot (*Rhizoctonia solani*)

Rotate crops with non-hosts. Do not plant into fields having significant undecomposed crop residues. Plant in well-drained sites and avoid over-irrigation. Practice careful cultivar selection as more upright plants are less susceptible.

azoxystrobin (Quadris): 0.40 to 0.80 fl oz/1000 row feet; PHI 0d, REI 4h, Group 11. Apply in-furrow or as a banded application.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.12 to 1.0 lb/A as a soil drench; PHI 0d, REI 4 h, Group 44.

boscalid (Endura): 8.0 to 11.0 oz/A; PHI 14d, REI 12h, Group 7. Suppression only.

iprodione (Rovral 4 F): 1.5 to 2.0 pt/A; PHI 14d, REI 24h, Group 2. Lettuce only. Direct application to soil and plant base. Do not cultivate after application.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

***Trichoderma asperellum*, *T. gamsii* (Bio-tam^{OG}):** See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

■ Gray Mold (*Botrytis cinerea*)

Avoid close planting and orient rows in the direction of prevailing winds. Do not plant in poorly drained areas. Plant on raised beds. Minimize damage to lettuce by cultural practices or other pathogens and pests. Avoid overhead irrigation. Do not plant where excessive plant residues are present. Transplanting mature plants results in more breakage. Direct seed Romaine lettuce as transplants are especially susceptible.

boscalid (Endura): 8.0 to 11.0 oz/A; PHI 14d, REI 12h, Group 7. Apply at seeding or transplant. A protective fungicide barrier is needed to maximize control.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 12.

penthiopyrad (Fontelis): 14.0 to 24.0 fl oz/A; PHI 3d, REI 12h, Group 7.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

***Ulocladium oudemansii* (BotryStop^{OG}):** 2-4 lbs/A; REI 4h, Group not applicable. Begin application when conditions are conducive to disease development.

■ Downy Mildew (*Bremia lactucae*)

Downy mildew is favored by cool, rainy weather. Night temperatures of 43°F to 50°F and day temperatures of 55°F to 70°F with 100% humidity are ideal for disease development. As temperatures increase, the disease disappears. Plant resistant cultivars. Use irrigation practices that reduce leaf wetness and humidity. Protect greenhouse grown transplants with fungicides so that the disease is not introduced into the field.

acibenzolar-S-methyl (Actigard 50 WG): 0.75 to 1.0 oz/A; PHI 7d, REI 12h, Group 21. Apply preventively on a 7-10 day schedule. See label for details.

ametoctradin & dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 & 40.

azoxystrobin (Quadris): 12.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Proceed with caution with regard to tank mixes and adjuvants. Do not rotate with other Group 11 fungicides.

copper compound (Badge X2^{OG}): 1.75 to 3.5 lb/A; PHI 0d, REI 48h, Group M1. Rate and REI vary with product.

Plant Nutrient Recommendation According to Soil Test Results for Lettuce, Endive, and Escarole

LETTUCE, ENDIVE, AND ESCAROLE	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	50-75	180	120	30-60	0-30	180	120	30-60	0
Sidedress 3-4 Weeks after Planting	30-50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	80-125	180	120	30-60	0-30	180	120	30-60	0

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette. Injury may occur to sensitive lettuce cultivars.

cyazofamid (Ranman): 2.75 fl oz/A; PHI 0d, REI 12h, Group 21.

cymoxanil (Curzate 60 DF): 3.2 to 5.0 oz/A; PHI 3d (head) and PHI 1d (leafy), REI 12h, Group 27. Must be applied as tank mix with a protectant fungicide.

dimethomorph (Forum): 6 fl oz/A; PHI 0d, REI 12h, Group 40. Must be applied as tank mix with another fungicide with a different mode of action.

famoxadone & cymoxanil (Tanos): 8 to 10 oz/A; PHI 1d, REI 12h, Groups 11 & 27. Tank mix with appropriate contact fungicide with a different mode of action. Do not make more than one application before alternating to a fungicide with a different mode of action.

fenamidone (Reason 500 SC): 5.5 to 8.2 fl oz/A; PHI 2d, REI 12h, Group 11. Do not make more than one application before alternating to a fungicide with a different mode of action. Do not alternate with Quadris.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. Must be tank mixed with a fungicide with a different mode of action.

fluxapyroxad & pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A. PHI 21d, REI 12h, Groups 7 & 11.

fosetyl-Al (Aliette WDG): 2 to 5 lb/A; PHI 3d, REI 12h, Group 33. Do not tank mix with copper compounds or apply in a spray solution with a pH less than 6.0.

mancozeb (Dithane F45): 1.2 to 1.6 qt/A; PHI 10d (head) or PHI 14d (leaf), REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 1.0 to 2.0 lb/A; PHI 10d, REI 48 h, Groups M3 & M1.

mandipropamid (Revus): 8 fl oz/A; PHI 1d, REI 4h, Group 40. Addition of a spreading/penetrating adjuvant is recommended.

oxathiapiprolin (Orondis Ultra A): 2.0-4.8 fl.oz/A; PHI 0d, REI 4h, Group 49. Begin foliar application prior to disease development.

propamocarb HCl (Previcur Flex): 2 pt/A; PHI 2d, REI 12h, Group 28.

pyraclostrobin (Cabrio EG): 16.0 oz/A; PHI 0d, REI 12h, Group 11.

■ Drop, White Mold (*Sclerotinia minor*)

Do not plant seed contaminated with sclerotia (small black hardened fungal survival structures). Avoid planting into severely infested fields. Rotate with non-host crops like grasses. Avoid excessive nitrogen fertilization and irrigate in the morning or with sub-surface drip irrigation to provide dry soil. Deep plow after harvest to bury sclerotia. Soil sterilization with chemicals, steam, or heat (solarization) treatments can significantly reduce inoculum levels. Incorporation of crop residues from brassica crops may provide a suppressive effect.

boscalid (Endura): 8.0 to 11.0 oz/A; PHI 14d, REI 12h, Group 7. Apply at seeding or transplant. A protective fungicide barrier is needed to maximize control.

Coniothyrium minitans (Contans WG^{OG}): Apply 1 to 4 lb/A in 20 to 50 gal water; REI 4h, Group NC. Spray on the soil surface and incorporate into the top 2" of soil. Fall application is best or 3 to 4 months before planting to allow for the biocontrol agent to infect the sclerotia of *Sclerotinia*.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 1.

fludioxonil (Cannonball WG): 7.0 oz/A; PHI 0d, REI 12h, Group 12.

fluxapyroxad & pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A. PHI 21d, REI 12h, Groups 7 & 11.

iprodisone (Rovral 4F): 1.5 to 2 pt/A; PHI 14d, REI 24h, Group 2. Lettuce only. Direct application to lower stems and branches and adjacent soil surface. Do not cultivate after application.

penthiopyrad (Fontelis): 16.0 to 24.0 fl oz/A; PHI 3d, REI 12h, Group 7.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

Trichoderma asperellum, T. gamsii (Bio-tam^{OG}): See label for in-furrow, drench, and broadcast rates; REI 4h, Group NC.

Ulocladium oudemansii (BotryStop^{OG}): 2-4 lbs/A; REI 4h, Group not applicable. Begin application when conditions are conducive to disease development.

■ Seed Decay

Use treated seed. Do not use treated seed for food, feed or oil purposes.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lb seed; REI 48h, Group 4. For *Pythium* damping-off protection.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* or *Phytophthora*.

thiram (Thiram SC): 8.0 fl oz/100 lb seed; REI 24h, Group M3.

■ Mosaic (Lettuce and Cucumber Mosaic Viruses)

Plant mosaic-indexed seed away from old lettuce fields.

■ Yellows

Do not plant lettuce or other sensitive crops in fields or areas having a history of this disease. Control alternate weed hosts. Control leafhoppers, which carry the disease-causing organism (phytoplasma).

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, Lettuce (*Nasonovia ribisnigri*)

The most common aphid present on lettuce is the lettuce aphid, of European origin, which overwinters on *Ribes* species including gooseberries and currants. Winged aphids that colonize lettuce are dark, while wingless females that reproduce on lettuce are pale yellow to green, sometimes reddish, with darker patches. Unlike other aphid species, they feed in the interior of the head, making them difficult to detect and to reach with insecticides. Scout plants at the seedling stage and before heads form. Check field margins, where infestations begin. If one planting becomes infested, use tillage to incorporate crop residue and prevent spread to later succession plantings. Potato aphid, green peach aphid or lettuce root aphid may also occur. See Potato for more information on potato aphid, and Pepper for more information on green peach aphid.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 21d, REI 24h, Bee: H, Group 1B. Green Peach Aphid. For head lettuce (crisphead type) only.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Versys): 1.5 fl oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

Beauveria bassiana (Mycotrol ESO): 8 to 32 oz/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Head lettuce only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Green peach aphid only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For control of green peach and suppression of potato aphid only.

dimethoate (Dimethoate 4EC): 8 oz/A; PHI 14d for escarole types and leaf lettuce, REI 48h, Bee: H, Group 1B. Not for head lettuce.

dinotefuran (Safari 20SG): 0.16 to 0.25 oz/1,000 sq ft or 3.5 to 5.5 oz/100 gal or 7 to 11 oz/A; REI 12h, Bee: H, Group 4. Transplants only while in greenhouse. Not for field use.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. For green peach and potato aphid only.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A for foliar application, 21 to 28 oz/A for soil application; PHI 1d foliar, PHI 21d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 1.3 oz/A foliar, 4.4 to 10.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. For foliar applications, apply only to fully leafed-up canopies.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with a companion labeled insecticide; for green peach aphid, must use companion insecticide.

malathion (Malathion 57 EC): 1.5 to 2 pt/A endive, 2 pt/A lettuce; PHI 7d for endive, PHI 14d for lettuce, REI 24h, Bee: H, Group 1B. Not for escarole.

methomyl (Lannate LV*): 1.5 to 3 pt/A; PHI 10d, REI 48h, Bee: H, Group 1A. For lettuce only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. Lettuce only.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9B. Translaminar. Apply when aphids first appear, before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils. Lettuce only.

spirotetramat (Movento): 4 to 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; PHI 3d, REI 12h, Bee: H, Group 4C.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

■ Aster Leafhopper (*Macrostelus quadrilineatus*)

See Carrot and Parsnip section for more information on aster leafhopper and the yellows mycoplasma that it vectors.

acephate (Orthene 97): 0.5 to 1 lb/A; PHI 21d, REI 24h, Bee: H, Group 1B. Aster leafhopper. For head lettuce (crisphead type) only.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A for potato leafhopper; 2.4 to 3.2 for other leafhoppers; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Head lettuce only.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 14d, REI 12h, Bee: H, Group 1A.

dimethoate (Dimethoate 4EC): 8 oz/A; PHI 14d for escarole types and leaf lettuce, REI 48h, Bee: H, Group 1B. Not for head lettuce.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.3 oz/A foliar, 4.4 to 10.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. For foliar applications, apply only to fully leafed-up canopies.

insecticidal soap (M-Pede^{OG}): 1.25 to 5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Lettuce only.

malathion (Malathion 57 EC): 2 pt/A; PHI 14d, REI 24h, Bee: H, Group 1B. For lettuce only.

methomyl (Lannate LV*): 1.5 to 3 pt/A; PHI 10d, REI 48h, Bee: H, Group 1A. For aster leafhopper on lettuce only.

permethrin (Pounce 25WP*): 3.2 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

tolfenpyrad (Torac): 14 to 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cabbage Looper (*Trichoplusia ni*)

An occasional pest of lettuce, especially in late season when migratory flights have brought high numbers of looper moths into New England. See Cabbage section for more information on cabbage looper.

acephate (Orthene 97): 1 lb/A; PHI 21d, REI 24h, Bee: H, Group 1B. For head lettuce (crisphead type) only.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group UN.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.4 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Head lettuce only.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through drip chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 10 to 17 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Apply when larvae are first observed.

flubendiamide (Belt SC): 1.5 oz/A; PHI 1d, REI 12h, Bee: L, Group 28. Active via ingestion.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h, Bee: H, Group 22.

methomyl (Lannate LV*): 1.5 to 3 pt/A; PHI 10d, REI 48h, Bee: H, Group 1A. For lettuce only.

methoxyfenozide (Intrepid 2F): 4 to 10 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Use lower rates when plants are small or infestations are light.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Not for escarole.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. Lettuce only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils. Lettuce only.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

tebufenozide (Confirm 2F): 6 to 8 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Use low rate for early season applications to young, small plants. Use of an adjuvant is recommended.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed on stems after dark. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Synthetic pyrethroids (Group 3A) may work best during cool spring weather. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 1 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Head lettuce only.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Lettuce only.

methoxyfenozide (Intrepid 2F): 4 to 10 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Use lower rates when plants are small or infestations are light.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 1d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Tarnished Plant Bug (*Lygus lineolaris*)

The tarnished plant bug (TPB) is a small (1/4") bronze-colored insect with a triangular marking on its back. TPB adults are highly mobile. The immature, or nymph stage is smaller and bright green, resembling an aphid, but much more active. Adults overwinter in weeds and crop residue and become active in early spring, laying eggs in plant tissue. Young tissue such as flower buds, immature fruit, and emerging leaves are preferred feeding sites compared to mature fruit, stems or leaves. There are 2 to 3 generations per year. There are both native and imported predators and parasites of TPB. The sucking injury from adults and nymphs can cause dieback of the growing tip, death and drop of buds or flowers, brown scars on leaf ribs, and distorted or stunted growth of leaves, pods, seeds or fruit. TPB injury in lettuce includes piercing of leaf ribs, which leaves a brown scar; this is especially noticeable on Romaine. The range of vegetable and fruit crops affected by TPB is great; field crops such as alfalfa and many weeds are also favored hosts. In this guide, celery, lettuce, bean and eggplant list TPB as a pest, but these are not the only crops that could be affected. In vegetables, TPB is generally not a seriously damaging pest unless the vegetation surrounding crop fields is serving as a source of large populations, and the crop offers more succulent feeding than the surrounding fields. Avoid planting lettuce near abandoned, weedy fields or alfalfa crops. While alfalfa may serve as a trap crop, mowing alfalfa may cause TPB to leave mowed fields for nearby vegetables causing TPB populations to increase. In strawberries, white sticky traps are used to detect adults and shaking flower trusses is used to detect nymphs; check small fruit alerts for TPB spring activity. Scout plants for signs of injury and for TPB adults or nymphs, especially in favorite, hidden feeding sites. Sweep nets can be used in crops that are not damaged by sweeping. Insecticides are warranted if damage is increasing and the crop stage is such that significant crop injury can be prevented.

beta-cyfluthrin (Baythroid* XL): 2.4 to 3.2 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 14d, REI 12h, Bee: H, Group 1A.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d, REI 12, Bee: L, Group 9C.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

insecticidal soap (M-Pede^{OG}): 1.25 to 5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. For lettuce only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

■ Slugs

Damage appears as shredded foliage. Look for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours. Grow plants away from moist, shaded habitats, use clean cultivation, control weeds, hand pick/crush slugs or scatter baits on the ground near infested plants. See the Cabbage section for more information on slugs.

iron phosphate (Sluggo: Snail and Slug Bait^{OG}): 20 to 44 lb/A; *PHI 0d, REI 0h, Bee: L, Group 9B.* Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; *REI 12h, Bee: L.* Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

See Soil Fumigation Outdoors, page 89. Proper use of Vapam can provide control of most weed species.

■ Stale Seedbed

See Stale Seedbed Technique, page 107. In place of herbicides, flaming can also be used.

carfentrazone (Aim EC): *REI 12h, Group 14.* Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Use 2-4 pts/A. Preplant or stale seedbed application. See Stale Seedbed Technique, page 107.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): *REI 12h, Group 8.* Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours of application. Mainly annual grass control, and should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

pronamide (Kerb SC): *PHI 25 to 55d (based on rate used), 24 hr REI, Group 3.* Must be applied prior to weed

emergence. Can be applied either pre-plant, post-plant, or postemergence to head or leaf lettuce, endive, escarole or radicchio greens in banded, bed-topped or broadcast applications. It is necessary to move Kerb into the root zone of germinating weeds to provide effective control (by overhead sprinkler irrigation, by rainfall, or by shallow mechanical incorporation). See label for rotation restrictions.

The rate required is dependent on soil texture, target weeds, and method of irrigation/incorporation. Read label carefully to select the proper rate based on your farm conditions. Apply 2.5 to 5.0 pts/A per acre for head lettuce, endive, escarole, and radicchio greens. Apply 1.25 to 5.0 pts/A per acre for leaf lettuce. Up to two applications are permitted and must be separated by at least 10 days. Total product applied must not exceed 5.0 pts/A.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Endive and escarole only. Apply 1 to 2 pts/A as a soil-incorporated treatment in spring or early summer prior to planting. Rate based on soil texture and crop, see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 14d, 24hr REI, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14 days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d head lettuce; PHI 15d for leaf lettuce, escarole, and endive, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PHYSIOLOGICAL DISORDERS

■ Tip Burn

This is a physiological condition caused by the plant's inability to obtain sufficient calcium due to rapid plant growth, excessive fertilization rates, or uneven water availability. Plant varieties resistant to this physiological disorder such as Ithaca and Mesa 659. Avoid excess fertilization. Irrigate with drip irrigation systems. Foliar calcium supplements may have some benefit.

OKRA

Okra is a warm season plant in the hibiscus family. The immature pods are used in soups, stir fries, pickles, and stews. The mucilage in okra acts as a thickening agent in soups, such as gumbo. Its nutritive value includes high fiber content; soluble in the form of gums and pectins that lower serum cholesterol, and insoluble fiber which helps maintain a healthy digestive system. Okra does best in warm weather and will die with frost. Most varieties have hairs on all parts of the plant that can cause skin irritation, so gloves and long sleeves may be needed for harvest.

Types and Varieties

OKRA VARIETIES	
Annie Oakley II	Jambalaya
Clemson Spineless	North and South
Cajun Delight	Zarah

Soil Fertility

Apply lime according to soil test to maintain a soil pH at 6.5-7.0.

If plants are to be grown on plastic mulch, the amount of nitrogen fertilizer to be sidedressed can be reduced, since leaching is minimized. If using transplants, apply a liquid fertilizer at transplanting, especially with cool soil conditions.

Use a high phosphorous starter fertilizer mixed at a rate of 3 lb/50 gal water. Apply 8 fl oz (1 cup) per transplant.

Planting

Seeds are sometimes soaked in water for 24 hours due to their hard seed coat to encourage germination. Transplants may be started in the greenhouse, preferably on a heat mat kept at 75-90°F, and transplanted to larger pots 6 weeks before planting into the field at the 3- to 4-leaf stage. Okra grows best at 75-90°F and should not be planted outdoors before the soil temperature reaches 65°F at 4" depth, usually in early June. Plastic mulch, row cover and high tunnels can be used to help achieve the heat requirements.

Plant populations range from 7,000 to 15,000 plants per acre, depending on the variety. Spacing ranges from 12" to 24" in the row (100-50 plants per 100 feet of row respectively) with 36" between rows.

Harvest and Storage

Flowering will occur as soon as 45 days after seeding, depending on the variety, and pods are ready for harvest 5-6 days after flowering. Pod tenderness (which is desirable) decreases as size increases. Most varieties will lose their tenderness when they exceed 3" in length. For this reason okra plantings must be picked almost every other day. Pods are harvested by twisting them off the plant or cutting with a knife. After harvest, room cool or use forced air to bring the okra down to 50-55°F at 85-90% relative humidity, where it may be stored for 7-10 days.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Okra is a tropical annual with a wide range of adaptation; it is very sensitive to cold temperatures and frost. Do not plant until soil temperatures have warmed in the spring.

■ Cercospora Leaf Spots (*Cercospora species*)

The pathogens survive on infected plant debris; remove and destroy diseased plant material. Plow crop debris under after harvest to speed up decomposition.

Plant Nutrient Recommendation According to Soil Test Results for Okra

OKRA	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	50	150	100	25-50	0	200	100	50	0
Sidedress 3-4 Weeks after Planting	40	0	0	0	0	0	0	0	0
Sidedress 6-8 Weeks after Planting	40	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	130	150	100	25-50	0	200	100	25-50	0

azoxystrobin plus difenoconazole (Quadris Top): 8-14 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 1.5 pt/A; PHI 3d, REI 12h, Group M5.

chlorothalonil plus cymoxanil (Ariston): 2-4.4 pints/A; PHI 3d, REI 12, Groups M3 & 27.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution with a pH less than 6.5 or tank mix with Aliette.

tebuconazole (Orion 3.6F): 4 to 6 fl oz/A; PHI 3d, REI 12h, Group 3.

sulfur (Microthiol Dispers^{OG}): 3.0 to 10.0 lb/A; PHI 0d, REI 24h, Group M2.

■ Damping-off (*Pythium* and *Rhizoctonia solani*)

Damping-off diseases are favored by cool, cloudy weather, wet soils, high humidity, compacted soils, and overcrowding. Avoid excessive irrigation, improve soil drainage, and relieve soil compaction. Remove and destroy affected plants and avoid transplanting diseased plants into the field. Seed treatments with biological control agents or fungicides are useful.

azoxystrobin (Quadris): 0.40 to 0.80 fl oz/ 1000 row feet; PHI 0d, REI 4h, Group 11.

mefenoxam (Apron XL): 0.16 to 0.64 fl oz/100 lbs seed; REI 48h, Group 4. Seed treatment.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/in a minimum of 20 gal. water/A; PHI 0d, REI 4h, Group 33. Do not apply to plants that are heat or moisture stressed. Copper phytotoxicity may occur if applied in alteration with copper.

thiram (Thiram 42 S): 6.0 lb/100 lb seed; REI 12h, Group M3.

■ Fusarium and Verticillium Wilts

Avoid planting in fields where these diseases are present. Rotate with non-solanaceous crops. Plant resistant varieties, if available. Consider soil fumigation. Soil solarization, fallowing, flooding, and biofumigation with brassica green manures may reduce soil populations of these pathogens. See Soil Fumigation Outdoors, page 89.

***Trichoderma asperellum*, *T. gamsii* (Bioten^{OG}):** See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

■ Fruit Rot (*Choanephora*)

Choanephora attacks senescent blossoms and grows into the fruit. No fungicides are labeled for control. Improve air circulation by proper plant spacing.

■ Powdery mildew (*Erysiphe cichoracearum*)

Maintain plant health by adequate fertilization as nutrient stressed plants are more susceptible to infection.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution with a pH less than 6.5 or tank mix with Aliette.

sulfur (Microthiol Dispers^{OG}): 3.0 to 10.0 lb/A; PHI 0d, REI 24h, Group M2.

■ Nematodes

Nematode control is very important for okra production. Fumigate fields in the fall. See Soil Fumigation Outdoors, page 89. Rotate with corn.

■ Yellow Vein Mosaic Virus (YVMV)

YVMV is the most important virus disease of Okra and it severely reduces growth and yield as well as causing fruit deformity. It is spread by whiteflies. There are no cures or chemical treatments for plant viruses. Remove and destroy affected plants. Plant resistant varieties. Control whiteflies to reduce disease incidence.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, Green Peach (*Myzus persicae*) and Melon (*Aphis gossypii*)

For more information see aphids in the Pepper section.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

afidopyropen (Sefina): 3 fl oz/A; PHI 0d, REI 12 h, Bee: L, Group 9D.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection. Suppression only.

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 7 to 14 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

malathion (Malathion 57 EC): 1.5 pt/A; PHI 1d, REI 12h, Bee: H, Group 1B.

spirotetramat (Movento): 4 to 5 oz/A; PHI 1d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Corn Earworm, also known as Tomato Fruitworm (*Helicoverpa zea*)

See Sweet Corn section for more information.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

carbaryl (Sevin XLR Plus): 1 to 1.5 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 7 to 13.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

flubendiamide (Belt SC): 1.5 oz/A; PHI 1d, REI 12h, Bee: L, Group 28. Must be ingested, ensure good coverage and apply to coincide with early threshold levels in developing larval population.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

methoxyfenozide (Intrepid 2F): 10 to 16 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Suppression only. Apply at first sign of feeding damage, or when threshold levels are reached.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant.

■ Japanese Beetles (*Popillia japonica*)

Beetles migrate from turf or pastures starting in July and skeletonize leaves.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

***Isaria fumosorosea* Apopka Strain 97 (PFR-97 20% WDG^{OG}):** 1 to 2 lb/A (soil applications only); PHI 0d, REI 4h, Bee: M, Group M.

malathion (Malathion 57 EC): 1.5 pt/A; PHI 1d, REI 12h, Bee: H, Group 1B.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

Outbreaks are often caused by the use of broad-spectrum insecticides. Two-spotted spider mites (TSSM) tend to be prone to pesticide resistance. Watch for white speckling on the upper surface of leaves or webbing on the undersurface around leaf veins. Avoid early-season, broad-spectrum insecticide applications for other pests. Use selective products whenever possible. With most miticides (not bifenazate), use 2 applications, approximately 5 to 7 days apart, to help control immature mites that were in the egg stage and protected during the first application. Alternate between products after 2 applications to help prevent or delay resistance. For more information on TSSM see the Eggplant section.

acequinocyl (Kanemite 15SC): 31 oz/A; PHI 1d, REI 12h, Bee: L, Group 20B. Do not use less than 100 gal water/A. Use of an adjuvant or surfactant is prohibited.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; PHI 3d, REI 12h, Bee: L, Group 25. Long residual, but not systemic; ensure complete coverage of upper and lower leaf surfaces and fruit.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

■ Stink Bugs

See Tomato section for information on stink bugs, including brown marmorated stink bug.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 1.5 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

Suggestions for weed management in okra include use of the Stale Seedbed Technique and use of plasticulture. Plasticulture is preferred for okra since it is such a warm season crop.

■ Stale Seedbed

See Stale Seedbed Technique, page 107. In place of herbicides, flaming can also be used.

carfentrazone (Aim EC): *REI 12h, Group 14.* Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Use 2-4 pt/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

Stale seed beds can be used between plastic mulch (be careful with flaming as it melts the plastic). Some hand weeding may be needed in the planting holes as okra grows slowly at first after transplanting. Apply the plastic at least 2 to 3 weeks prior to planting and kill the weeds between the mulch prior to setting the okra plants on the plastic.

■ Herbicides Used Preemergence to Weeds

trifluralin (Treflan HFP): *REI 12h, Group 3.* Apply 1 to 2 pts/A as a soil-incorporated treatment prior to planting. Select rate based on soil texture and crop, see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation.

■ Herbicides Used Pre- and Postemergence to Weeds

mesotrione (Callisto): *PHI 28d, REI 12h, Group 27.* Callisto can be applied as a row middle OR a hooded post-direct treatment (but not both) for weed control in okra. Do not make more than one application of Callisto per okra crop. Injury risk is greatest on coarse-textured soils (sand, sandy loam or loamy sand). Do not apply Callisto as a broadcast preemergence or broadcast postemergence application to okra or severe injury will occur. Do not apply Callisto directly over the planted okra row or severe crop injury may occur. Controls many annual broadleaf weeds, including common lambsquarter and triazine resistant biotypes. Temporary injury, appearing as whitening of the foliage after emergence, may occur. Varieties may differ in sensitivity to mesotrione.

Preemergence row-middle application: Apply Callisto at a rate of 6.0 oz/A as a banded application to the row middles prior to weed emergence. Leave one foot of untreated area over the okra row or 6" to each side of the planted row. For banded applications, the application must be made to account for band width, i.e. to deliver 6.0 fl oz per treated acre.

Postemergence hooded application: Apply Callisto at a rate of 3.0 fl oz/A as a postemergence directed application using a hooded sprayer for control or partial control of the weeds listed in Table 28, page 109. Okra must be at least 3" tall at the time of this application. It is recommended that a nonionic surfactant (NIS) type adjuvant at a rate of 0.25%

v/v be added to the spray solution. For postemergence hooded applications, the spray equipment must be set up to minimize the amount of Callisto that contacts the okra foliage or crop injury will occur. For best postemergence results, Callisto must be applied to actively growing weeds.

prometryn (Caparol 4L): *PHI 14d, REI 12h, Group 5.* Primarily controls annual broadleaf weeds. Annual grasses may only be suppressed. Can be used preemergence and/or post-directed to okra. Make a single preemergence broadcast application of Caparol 4L after planting before crop emergence at the rate of 3.0 pt/A. For two applications make the first preemergence after planting, before crop emergence at the rate of 1.5 pt/A and the second post-directed when okra plants are at 7-9 leaf stage at the rate of 1.5 pt/A. Apply post-directed before weeds are 2 inches tall. Do not exceed one preemergence and one post-directed application per crop cycle. Do not exceed 3 pt/A of Caparol 4L per crop cycle.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* For use between rows after crop establishment. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

halosulfuron (Sanda): *PHI 30d, REI 12h, Group 2.* Apply between rows of okra for control of broadleaf weeds. Avoid crop contact. If plastic mulch is used, keep the herbicide off the plastic. DO NOT allow Sandea to contact the planted crop or crop injury will occur. See label for additional precautions. Excellent on velvetleaf, smartweed, ragweed, pigweed. Good on yellow nutsedge and morning glory. Use 0.5 to 1.5 oz/A per application. Do not apply more than 2 times per season and do not exceed 2 oz/A per year. See label for list of weeds and other precautions. Weed control may be reduced without the use of a surfactant.

paraquat (Gramoxone SL 2.0*): *REI 12h, Group 22.* For use between rows after crop establishment. Apply up to 2 pt/A as a directed and shielded spray to emerged weeds between rows when weeds are succulent and weed growth is less than 6". Maximum 3 applications per year, not to exceed a total of 8 pt/A per season. Allow 14 days between applications. Use precision directed spray application equipment adjusted to prevent spray contact with crop plants. Crop contact by the spray will cause severe injury or death. Do not exceed 30 psi nozzle pressure or spray under conditions which may cause excessive drift.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a DIRECTED/SHIELDED SPRAY; contact with crop will cause injury. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray

solution per acre; complete coverage of weed foliage is essential. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

ONION, SCALLION, AND SHALLOT

Bulbing onion, scallion, and shallot, along with garlic and leek, are members of the genus *Allium*. The characteristic flavors of *Allium* family members come from sulfur-containing compounds produced by these plants.

The bulbing onion, *Allium cepa*, appears to have originated near the intersection of Europe and Asia, whereas the bunching onion or scallion, *Allium fistulosum* may have originated in China.

Types and Varieties

Bulbing onions form bulbs in response to day length. Only long-day and intermediate-day types are recommended for summer harvest in New England since these types require at least 13 hours of daylight. Short-day onions begin forming bulbs when days are 10-12 hours long and are typically grown in southern regions of the U.S. where they are planted in the winter. Recently, some researchers and farmers in New England have been planting onions in tunnels in the fall for spring harvest. The University of New Hampshire research report on overwintering onions includes planting details and trialed varieties (see https://extension.unh.edu/resources/files/Resource005477_Rep7652.pdf). Shallots form clusters of bulbs. While shallots have traditionally been propagated vegetatively, hybrid cultivars that can be grown from seed are now available. Scallions are species of onion that does not form a fully developed bulb. They are planted from seed and commonly sold in bunches.

ONION, SHALLOT, AND SCALLION VARIETIES	
Scallion/Bunching Onion Evergreen Hardy White Ishikura Improved Southport White Bunching	Onion - Yellow Storage Northstar (80) Bridger (90) New York Early (98) Patterson (104)
Shallot Ambition Conservor	Cortland (105) Prince (106) Crocket (114)
Onion - Sets Ebenezer Stuttgart	Onion - Red Storage Red Bull (104) Redwing (114)
Onion - Sweet, non-storing Ailsa Craig (110) Candy (85)	Onion - Overwintering Bridger Gatekeeper Hi-Keeper
Onion - Sweet Spanish Super Star (100) Yellow Sweet Spanish (120)	Electric (red) Desert Sunrise (red) Red Rock (red)
The number in parentheses is the approximate number of days to maturity from seeding.	

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8. Onions and leeks do not tolerate acid soil, especially in early growth stages. If the magnesium level is

high, a lime high in calcium (calcitic lime) should be used to maintain a high calcium level.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15). These sources may also result in high soil nitrogen levels late in the season. Excessive nitrogen late in the season from any source can delay maturity and reduce storability of onions.

Onion flavor is determined by cultivar type, temperature and irrigation, and sulfur fertility. Growers wishing to produce mild-flavored onions for retail sale should choose mild cultivar types, irrigate regularly up to harvest, and maintain soil sulfur levels between 35 and 55 lb/A. Excessive sulfur levels in soils or fertilizers will increase pungency.

Planting

Bulbing onion and shallot. Sow transplants in late February or early March, 10-12 weeks before setting in field. Direct seed onions in spring as soon as soil can be worked. Seeding should be completed by late April or mid-May at the very latest to allow time for adequate plant growth before bulb initiation occurs. Plant 2-4 rows per bed, 9"-18" between rows and 3"-4" apart within rows for transplants. Spacing will affect bulb size. For direct seeding, aim for a stand of 6-9 plants per foot. This can be increased to 9-12 plants per foot if double shoe precision seeders are used. This requires 5-6 lb of seed per acre (about 0.5 oz per 100 feet of row). Instead of transplants, some growers use sets to plant all or some of their crop. Sets are small bulbs (about 1/2") raised the prior year and stored over the winter. This provides for an early harvest (mid-summer), but larger sets can be prone to bolting (premature flowering). Sets should be planted as soon as the soil has dried and can be worked. Spacing is the same as for transplants. Some growers are finding success using black or white-on-black plastic mulch on raised beds for sets or transplants.

Scallion. In addition to early spring planting, mid-summer plantings can be used to produce fall harvests. Even moisture must be maintained throughout germination for direct-sown scallions. Seed in rows 2-3" wide, spaced 4" apart.

Harvest and Storage

Bulbing onion and shallot: Late, hard, pungent varieties with good skin retention are preferable for winter storage. Undercutting several days before harvesting can improve keeping quality. It is best to undercut when most of the plants have 2 leaves that are still partially green. Allowing leaves to completely dry down before undercutting can result in excessive loss of skin during harvest. To develop best skin color, onions should be cured for 2 weeks at 75°-80°F and 70%-80% relative humidity. After curing, lower temperature gradually to as near to 32°F as practical without freezing. Cooling too rapidly, followed by a few warm days, can cause moisture condensation, resulting in bulb staining, sprouting and decay. Maintain storage relative humidity at 65%-70%, and maintain sufficient air flow to keep cool air moving around bulbs.

Scallion. Scallions, or fresh bunching onions, can be harvested anytime after they are pencil-sized. To maintain good post-harvest quality, they should be cooled to 39°F within 4-6 hours of harvest. Scallions can be stored for 7-10 days at 32°F.

Sprout Inhibition

For long-term storage of bulbing onions or shallots, select storage varieties. Pungent dry onions can be stored for 6-9 months at 32°F. For very long-term storage, a sprouting inhibitor, maleic hydrazide (2 gal of Royal MH-30/A in a minimum of 30 gal/A), may be applied when about 50% of the tops are down, the bulbs are mature, the necks are soft and five to seven of the leaves are still green. See the label for details.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Botrytis Leaf Blight

Avoid close planting and orient rows in the direction of prevailing winds. Do not plant on poorly-drained areas. Plow under crop debris after harvest. Remove cull piles and practice crop rotation. Avoid excessive nitrogen fertilization as this increases canopies and susceptibility. Plant less susceptible cultivars. Irrigate early in the day to reduce leaf wetness periods. Incorporate crop residues after harvest. Apply fungicides based on a disease forecast system (i.e., BOTCAST). Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu).

For dry bulb onions:

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; PHI 7d, REI 12h, Groups 11 & M5.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; PHI 7d, REI 12h, Groups 11 & 3.

azoxystrobin plus propiconazole (Quilt): 14.0 to 27.5 fl oz/A; PHI 14d, REI 12h, Groups 11 & 3.

boscalid (Endura): 6.8 oz/A; PHI 7d, REI 12h, Group 7.

chlorothalonil (Bravo Weather Stik): 1.0 to 3.0 pt/A; PHI 7d, REI 12h, Group M5. To suppress Botrytis neck rot in storage, a minimum of 3 weekly applications prior to lifting using 1.25 to 1.8 lb/A is recommended.

cyprodinil (Vanguard): 10.0 oz/A; PHI 7d, REI 12h, Group 9.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 7d, REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage.

fluazinam (Omega 500F): 1.0 pt/A; PHI 7d, REI 12h to 24h (24h for hand weeding), Group 29.

fluxapyroxad plus pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A; PHI 7d, REI 12, Groups 7 & 11. For best results, begin applications before disease onset.

iprodione (Rovral 4F): 1.5 pt/A or 1.0 pt/A (if tank-mixed); PHI 7d, REI 24h, Group 2.

mancozeb (Dithane F45): 2.4 qt/A; PHI 7d, REI 24h, Group M3.

penthiopyrad (Fontelis): 16 to 24 oz/A; PHI 3d, REI 12h, Group NC.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

potassium phosphite plus chlorothalonil (Catamaran): 4.0 to 7.0 pt/A; PHI 7d, REI 12, Groups 33 & M5.

propiconazole (Tilt): 4.0 to 8.0 oz/A; PHI 14d, REI 12, Group 3.

pyraclostrobin plus boscalid (Pristine): 14.5 to 18.5 oz/A; PHI 7d, REI 12h, Groups 11 & 7. Do not make more than 2 sequential applications of Pristine before alternating with a fungicide with a different mode of action.

pyrimethanil (Scala SC Fungicide): 18.0 fl oz/A; PHI 7d, REI 12h, Group 9.

For green onions, leeks or shallots:

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; PHI 14d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; PHI 1d, REI 12h, Groups 11 & 3.

azoxystrobin plus propiconazole (Quilt): 14.0 to 27.5 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

boscalid (Endura): 6.8 oz/A; PHI 7d, REI 12h, Group 7. Use higher rate and shorter interval when disease pressure is high. Do not make more than 1 application of Endura before alternating with a fungicide with a different mode of action (FRAC group).

Plant Nutrient Recommendation According to Soil Test Results for Onion, Scallion, and Shallot

ONION, SCALLION, AND SHALLOT	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	80-100	150	100	25-50	0	175	150	50	0
Sidedress 4-5 Weeks after Planting	50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	130-150	150	100	25-50	0	175	150	50	0

chlorothalonil (Bravo Weather Stik): 1.5 to 3.0 pt/A; *PHI 14d, REI 12h, Group M5*. When disease is present, use the higher rate.

cyprodinil (Vanguard): 10.0 oz/A; *PHI 7d, REI 12h, Group 9*.

cyprodinil plus fludioxonil (Switch 62.5 WDG): 11.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12*.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; *PHI 14d, REI 12h, Group 3 & 9*.

fluxapyroxad plus pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A; *PHI 7d, REI 12, Groups 7 & 11*. For best results, begin applications before disease onset.

penthiopyrad (Fontelis): 16.0 to 24.0 oz/A; *PHI 3d, REI 12h, Group NC*.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19*.

potassium phosphite plus chlorothalonil (Catamaran): 4 to 7 pt/A; *PHI 14d, REI 12, Groups 33 & M5*.

propiconazole (Tilt): 4.0 to 8.0 oz/A; *PHI 0d, REI 12, Group 3*.

pyraclostrobin plus boscalid (Pristine): 14.5 to 18.5 oz/A; *PHI 7d, REI 12h, Groups 11 & 7*. Do not make more than 2 sequential applications of Pristine before alternating with a fungicide with a different mode of action.

primethanil (Scala SC Fungicide): 18 fl oz/A; *PHI 7d, REI 12h, Group 9*.

■ Neck Rot (*Botrytis alli*)

Primarily a storage disease. Do not apply nitrogen late in the season and avoid high-density planting. Undercut bulbs to promote drying. Allow the tops to dry completely and have tight necks before topping. Avoid condensation on bulbs during storage. Maintain storage environment at 32°F to 33°F and 70% to 75% relative humidity. Fungicides applied to control *Botrytis* blight may also decrease neck rot.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; *PHI 14d, REI 14h, Groups 11 & M5*. Suppression only. See label for tank mix precautions.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12*. Suppression only.

fluazinam (Omega 500F): 1 pt/A; *PHI 7d, REI 48h, Group 29*.

fluxapyroxad + pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A; *PHI 7d, REI 12, Groups 7 & 11*. For best results, begin applications before disease onset.

iprodione (Rovral 4F): 1.5 pt/A or 1.0 pt/A (if tank-mixed); *PHI 7d, REI 24h, Group 2*.

mancozeb (Dithane M45): 2.4 qt/A; *PHI 7d, REI 24h, Group M3*.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19*.

pyraclostrobin plus boscalid (Pristine): 14.5 to 18.5 oz/A; *PHI 7d, REI 12h, Groups 11 & 7*.

primethanil (Scala SC Fungicide): 18.0 fl oz/A; *PHI 7d, REI 12h, Group 9*.

■ Downy Mildew (*Peronospora destructor*)

The fungus overwinters in infected bulbs or sets and on other host plants, in cull piles, and in fall-seeded onion. Only a few spores are needed to initiate an epidemic. Eliminate cull piles, volunteer onion plants, and wild *Allium* species. Practice a 3- to 4-year rotation. Plant only on well-drained land. Apply fungicides when mildew is present in the area and weather favors disease increase based upon a disease forecasting system (i.e., DOWNCAST). Disease development, based on weather conditions near your farm, can be monitored online (www.newa.cornell.edu).

For dry bulb onions:

acibenzolar-s-methyl (Actigard 50 WG): 0.75 to 1.0 oz/A; *PHI 7d, REI 12h, Group 21*. Actigard acts as a plant activator and should be applied preventatively.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; *PHI 0d, REI 12h, Groups 45 and 40*.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11*.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.7 pt/A; *PHI 7d, REI 12h, Groups 11 & M5*. See label for tank mix precautions.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; *PHI 0d, REI 48h, Group M1*. Can cause phytotoxicity to leaves. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyazofamid (Ranman 400 SC): 2.75 to 3.0 fl oz/A; *PHI 0d, REI 12h, Group 21*.

dimethomorph (Forum): 6.0 fl oz/A; *PHI 0d, REI 12h, Group 40*. Forum must be applied as a tank mix with another fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; *PHI 3d, REI 12h, Groups 11 & 27*. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 fl oz/A; *PHI 7d, REI 12h, Group 11*. Do not make more than 1 application of Reason before alternating to a non-Group 11 fungicide.

fluazinam (Omega 500F): 1.0 pt/A; *PHI 7d, REI 48h, Group 29*.

fluxapyroxad plus pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A; *PHI 7d, REI 12, Groups 7 & 11*. For best results, begin applications before disease onset. For suppression only.

fosetyl-AI (Aliette): 2.0 to 3.0 lb/A; *PHI 7d, REI 12h, Group 33*. Do not tank mix with copper.

mancozeb (Dithane M45): 2.4 qt/A; *PHI 7d, REI 24h, Group M3*.

mancozeb plus copper hydroxide (ManKocide): 2.5 lb/A; *PHI 7d, REI 48h, Groups M3 & M1*.

mandipropamid (Revus): 8.0 fl oz/A; *PHI 7d, REI 4h, Group 40*.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; *PHI 7d, REI 48h, Groups 4 & M5*.

mefenoxam plus copper hydroxide (Ridomil Gold Copper): 2.0 lb/A; *PHI 10d, REI 48h, Groups M3 & M1*.

mefenoxam plus mancozeb (Ridomil Gold MZ): 2.5 lb/A; PHI 7d, REI 48h, Groups 4 & M3.

oxathiapiprolin plus chlorothalonil (Orondis Opti): 1.75 to 2.5 pt/A; PHI 7d, REI 12h, Groups 49 & M5.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; PHI 7d, REI 4h, Groups 49 & 40.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; PHI 0d, REI 4h, Group 33. Do not apply to heat or moisture stressed plants or to plants recently treated with copper.

potassium phosphite plus chlorothalonil (Catamaran): 4.0 to 7.0 pt/A; PHI 7d, REI 12, Groups 33 & M5.

pyraclostrobin (Cabrio EG): 12.0 oz/A; PHI 7d, REI 12h, Group 11.

pyraclostrobin plus boscalid (Pristine): 18.5 oz/A; PHI 7d, REI 12h, Groups 7 & 11. For suppression only. Rotate with a downy mildew fungicide with a different mode of action.

Green or bunching:

ametocradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 and 40.

azoxystrobin (Quadris): 9.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 2.4 to 3.7 pt/A; PHI 14d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

copper hydroxide (Kocide 3000): 0.75 to 1.5 lb/A; PHI 0d, REI 48h, Group M1. Can cause phytotoxicity to leaves. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyazofamid (Ranman 400 SC): 2.75 to 3.0 fl oz/A; PHI 0d, REI 12h, Group 21.

dimethomorph (Forum): 6.0 fl oz/A; PHI 0d, REI 12h, Group 40. Forum must be applied as a tank mix with another fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fluxapyroxad plus pyraclostrobin (Merivon): 8.0 to 11.0 fl oz/A; PHI 7d, REI 12, Groups 7 & 11. For best results, begin applications before disease onset. For suppression only.

mandipropamid (Revus): 8.0 fl oz/A; PHI 7d, REI 4h, Group 40.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; PHI 14d, REI 48h, Groups 4 & M5.

mefenoxam plus copper hydroxide (Ridomil Gold Copper): 2.0 lb/A; PHI 7d, REI 48h, Groups M3 & M1.

oxathiapiprolin plus chlorothalonil (Orondis Opti): 1.75 to 2.5 pt/A; PHI 14d, REI 12h, Groups 49 & M5.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; PHI 7d, REI 4h, Groups 49 & 40.

potassium phosphite + chlorothalonil (Catamaran): 4.0 to 7.0 pt/A; PHI 14d, REI 12, Groups 33 & M5.

pyraclostrobin (Cabrio EG): 12.0 oz/A; PHI 7d, REI 12h, Group 11.

pyraclostrobin plus boscalid (Pristine): 18.5 oz/A; PHI 7d, REI 12h, Groups 7 & 11. For suppression only. Rotate with a downy mildew fungicide with a different mode of action.

■ Purple Blotch (*Alternaria porri*, *Stemphylium vesicarium*)

Purple Blotch can be caused by either fungus alone or both fungi together. Avoid Sweet Spanish onion because they are extremely susceptible. Plow under crop residues after harvest. Rotate with non-hosts. Select sites and practice irrigation to enhance rapid drying of foliage. Apply fungicides as canopy becomes denser and leaf-wetness periods increase. Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu).

azoxystrobin (Quadris): 6.0 to 12.0 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 to 3.2 pt/A; PHI 7d (dry) and 14d (green), REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 12.0 to 14.0 fl oz/A; PHI 7d, REI 12h, Groups 11 & 3.

azoxystrobin plus propiconazole (Quilt): 14.0 to 27.5 fl oz/A; PHI 14d (dry) and 0d (green), REI 12h, Groups 11, 7 & 3).

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel[®]):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

boscalid (Endura): 6.8 oz/A; PHI 7d, REI 12h, Group 7.

chlorothalonil (Bravo Weather Stik): 1.0 to 3.0 pt/A; PHI 7d (dry) and 14d (green), REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75-1.5 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyprodinil (Vanguard): 10.0 oz/A; PHI 7d, REI 12h, Group 9.

cyprodinil plus fludioxonil (Switch 62.5 WDG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 7d (dry bulb); PHI 14d (green), REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 7d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

fluzinam (Omega 500F): 1.0 pt/A (dry bulb only); PHI 7d, REI 12-24h, Group 29.

fluxapyroxad plus pyraclostrobin (Merivon): 5.5 to 11 fl oz/A; PHI 7d, REI 12, Groups 7 & 11. For best results, begin applications before disease onset.

iprodione (Rovral 4F): 1.5 pt/A (dry bulb only); *PHI 7d, REI 24h, Group 2.* Do not make more than 5 applications per season. If tank-mixing with another chemical registered for purple blotch, reduce iprodione rate to 1 pt/A.

mancozeb (Dithane F45): 2.4 qt/A (dry bulb only); *PHI 7d, REI 24h, Group M3.*

mancozeb plus copper hydroxide (ManKocide): 2.5 lb/A (dry bulb only); *PHI 7d, REI 48h, Groups M3 & M1.*

penthiopyrad (Fontelis): 16.0 to 24.0 oz/A; *PHI 3d, REI 12h, Group NC.*

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19.*

potassium phosphite plus chlorothalonil (Catamaran): 4.0 to 7.0 pt/A; *PHI 14d, REI 12, Groups 33 & M5.*

propiconazole (PropiMax EC): 4.0 to 8.0 fl oz/A; *PHI 14d bulb; PHI 0d green, REI 12h, Group 3.*

pyrimethanil (SCALA SC Fungicide): 18 .0fl oz/A; *PHI 7d, REI 12h, Group 9.*

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; *PHI 7d, REI 12h, Group 11.* Do not exceed 6 applications per season or 72 oz/A. Do not rotate with other Group 11 fungicides.

pyraclostrobin plus boscalid (Pristine): 10.5 to 18.5 oz/A; *PHI 7d, REI 12h, Groups 7 & 11.* Do not rotate with another Group 11 fungicide.

pyrimethanil (Scala SC): 18 fl oz (alone) 9 fl oz (tank mixed)/A; *PHI 7d, REI 12h, Group 9.*

tebuconazole (Orius 3.6F): 4.0 to 6.0 fl oz/A (for dry onion); *PHI 7d, REI 12h, Group 7.*

■ White Rot (*Sclerotium cepivorum*)

White rot is associated with soil-borne inoculum; repeated cropping of *Allium* species results in increased disease over time. The sclerotia can persist in the soil for up to 20 years in the absence of a host. Select fields with no history of this disease. Use only disease-free transplants. Soil fumigation may be useful. Stimulating the sclerotia to germinate with onion exudate mimics (diallyl disulphide) can reduce soil inoculum.

azoxystrobin plus propiconazole (Quilt Xcel): 17.5 to 26 fl oz/A; *PHI 14d, REI 12h, Group 11 & 3.*

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.12 to 1.0 lb/A as a soil drench; *PHI 0d, REI 4 h, Group 44.*

boscalid (Endura): 6.8 oz/A; *PHI 7d, REI 12h, Group 7.* Apply in-furrow.

cyprodinil plus fludioxonil (Switch 6.25 WG): 7.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12.* Apply at planting as in-furrow spray.

fludioxonil (Cannonball): 7.0 oz/A (0.5 oz/1,000 ft row); *PHI 7d, REI 12h, Group 12.*

penthiopyrad (Fontelis): 16.0 to 24.0 oz/A; *PHI 3d, REI 12h, Group NC.*

tebuconazole (Orius 3.6F): 20.5 fl oz/A (dry onion); *PHI 7d, REI 12h, Group 7.* Apply in a 4-6 inch band into/over each furrow. May also be applied by chemigation.

thiophanate methyl (Topsin M 70WP): 2.0 lb/A; *REI 72h, Group 1.* Apply in furrow.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Bulb Mites

Two genera of mites are known to infect species of *Allium*. The dry bulb mite (*Aceria tulipae*) is an eriophyid mite that survives on cultivated *Allium* species. Bulb mite species in the genus *Rhizoglyphus* can also be troublesome on alliums. Bulb mites overwinter in soil on debris, stored onions and garlic, and in garlic seed pieces. They are moved from field to field with soil on equipment, boots, etc., and planting infested garlic. They are particularly troublesome in storage, causing desiccation and creating wounds that allow for entry of pathogens.

Bulb mites are favored by mechanical injury, disease, cool soil temperatures, and soils with high organic matter content. Avoid adding manure and use fallow periods to eliminate crop residue. In smaller plantings, removing culls from the field immediately after harvest will reduce overwintering populations. Dark plastic mulch will increase soil temperatures and control mites. Plant clean seed and rotate out of alliums for at least four years after an infestation. Avoid planting alliums directly after brassicas, corn, grain, or grass cover crops.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant during the day and feed on leaves after dark. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Synthetic pyrethroids may work best during cool spring weather. All synthetic pyrethroid restricted use (*) insecticides listed to control thrips on onions are also registered to control cutworm on this crop. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested;

apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

gamma-cyhalothrin (Declare*): .077 to 1.28 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.60 oz/A; PHI 14d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 3 pt/A; PHI 7d, REI 48h, Bee: H, Group 1A. For green and dry onions. Add wetting agent to improve coverage. For black and variegated cutworm only.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 1d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

■ Onion Maggot (*Delia antiqua*)

Infestations may reduce young plant stands, cause plants to wilt and yellow, or damage bulbs. There are 3 generations each year. Effective control of the first generation (mid-May to June), which causes the most destruction, and minimizing mechanical and chemical damage to onions throughout the season, will reduce or eliminate damage by later generations. Rotate crops to keep maggot populations low; greater distances are more effective. Cumulative growing degree days (GDD) can be used to monitor the activity of onion maggot fly in your area: peak flight for the first generation is at 735 GDD, base 40°F. Delay planting until after first flight is finished and soil temperatures are high enough to kill eggs (95°F). Planting in late-May is more likely to be safer than the first half of May. Cover recently seeded or transplanted crops with floating row covers as a barrier against cabbage root maggot flies, placing the cover as soon as the transplants are set. Gathering culls into deep piles will limit reproduction to surface layers and reduce populations more than deep plowing or harrowing after harvest. Biological controls, including naturally-occurring fungal diseases, predaceous ground beetles, and soil applications of the entomopathogenic nematode *Steinernema feltiae* can all reduce onion maggot numbers. Nematodes can be applied to transplants, in transplant water, or as a post-transplant drench. Rates of 100,000 to 125,000 infective juveniles per transplant have been shown to be needed to achieve reduction in damage. Nematodes need a moist soil environment to survive. If using an insecticide, soil drench applications targeting the seed furrow or base of transplants, using at least 100-200 gal of water per acre to help the insecticide penetrate the root zone are the most effective.

chlorpyrifos (Lorsban 4E): 32 oz/A at-plant or 1 quart/A postplant soil drench; PHI 60d, REI 24h, Bee: H, Group 1B. For direct seeded onions, apply as band over row at planting in a minimum of 40 gal/A; for seedlings or transplants, apply at base of plants during peak egg laying

time in a minimum of 100 gal/A. Dry bulb onions only. DO NOT make more than 2 applications per year (at-plant plus post-plant).

diazinon (Diazinon* AG500): 2 to 4 qt/A; REI 3d, Bee: H, Group 1B. Broadcast and incorporate just before planting. Will not control organophosphate-resistant onion maggots. For bulb and green onions. DO NOT make more than one application per year.

■ Onion Thrips (*Thrips tabaci*)

Onion thrips range in color from yellow to black and are only 1/16" in length. They spend the winter as adults in crop remnants, alfalfa, wheat, greenhouses and weeds along the border of crop fields. Thrips have rasping mouth parts which they use to tear open plant cells and feed on inner juices. Feeding occurs in protected areas between leaves. Damage may appear as silver lines, white patches, tip dieback and curling, slowed growth, reduced bulb size and yields, or result in plant death. Populations are favored by hot, dry weather. Plants are most sensitive when bulbs are forming and still small. Heavy rain or overhead irrigation can lower populations quickly. Lacewing larvae, pirate bugs and predatory thrips are important natural enemies. Reduce populations by cleaning up crop residue after harvest to limit overwinter sites. Do not plant onions near alfalfa, clover, cucurbits or brassica crops that can harbor large populations of thrips, which may migrate to onions when these crops are cut or harvested.

Scout plants along field margins where infestations build early. Begin applications when damage is first noticed or when there are 3 or more thrips per leaf. Repeat applications at 7- to 10-day intervals. From 3 to 6 applications may be necessary, but rotate between insecticide groups after 2 applications to help prevent resistance. Use a shorter interval in hot weather. Use spreader-sticker for better coverage. Apply in early evening, using high pressure and 100 gal water/A for best results.

acetamiprid (Assail 30SG): 5 to 8 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

***Beauveria bassiana* (Mycotrol ESO):** 0.25 qt to 1 qt/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M. Suppression only.

***Chenopodium* extract (Requiem EC):** 1.5 to 3 qts/A; PHI 0d, REI 4h, Bee: L. Begin application as soon as thrips are seen. Thoroughly cover foliage.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Suppression only.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): .102 to 1.54 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 14 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{0G}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression/repellence only. Good coverage into plant crown is essential. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 14d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57EC): 1.5 pt/A; PHI 3d, REI 12h, Bee: H, Group 1B.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L.

methomyl (Lannate* LV): 3 pt/A; PHI 7d, REI 48h, Bee: H, Group 1A. For green and dry onions. Add wetting agent to improve coverage. Begin application before populations reach 3 to 5 thrips per plant.

permethrin (Pounce* 25WP): 9.6 to 19.2 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. For dry bulb onions only

petroleum oil (Suffoil X^{0G}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pyrethrin (PyGanic EC5.0^{0G}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Esteem 0.86EC): 8 oz/A; PHI 3d, REI 12h, Bee: L, Group 7D. Dry bulb onions only. Suppression only.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spinosad (Entrust SC^{0G}): 4 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Suppression only. Use adjuvant for better control.

spinetoram (Radiant SC): 6 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Thorough coverage is essential. Efficacy improves with the addition of an adjuvant.

spirotetramat (Movento): 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

zeta-cypermethrin (Mustang*): 3.2 to 4.3 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107. In place of herbicides, flaming can also be used.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): restricted use. Onions only. REI 12h, Group 22. Use 2-4 pts/A.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): REI 12h, Group 8. Dry bulb onion and dry bulb shallot only. Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or incorporated by irrigation within 36 hours of application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

dimethenamid (Outlook): PHI 30d, REI 12h, Group 15. Can be used for dry bulb onion and shallot, and also for green onion (leeks, spring onions or scallions, Japanese bunching onions, green shallots or eschalots). If applications are made to transplanted green onions, DO NOT apply until transplants are in the ground and soil has settled around transplants with several days to recover. This herbicide is a root and shoot growth inhibitor that controls susceptible germinating seedlings before or soon after they emerge from the soil. Do not apply until onion has reached the 2 true-leaf stage or significant crop injury can occur. May be applied as a single application (up to 21 oz/A) or used in split applications. For split applications do not exceed a total of 21 oz/A per season. An initial application of 10 to 14 oz/A can be followed by another application of the remaining 7 to 11 oz/A. Applications must be a minimum of 14 days apart. Application rates are influenced by soil organic matter content. See label for info on application rates depending on soil type and organic matter content. See label for info on tank mixing with other herbicides.

DCPA (Dacthal 75WP): REI 12h, Group 3. Select rate for preemergence use based on soil type and weeds targeted for preemergence control. Good control of most annual grasses; fair on redroot pigweed, lambsquarter, and purslane. Apply to weed-free soil; will not control existing weeds. Can be applied at seeding or transplanting and/or at layby. Can be sprayed directly over transplants without injury. A layby application can be made on onions either alone or in addition to a Dacthal preemergence treatment up to 14 weeks after planting at rates up to 14 lb/A on any soil type. If weeds emerge prior to layby, the onions should be cultivated or weeded prior to application. Preplant incorporation not recommended.

s-metolachlor (Dual Magnum): REI 12h, Group 15. MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. This is a restricted label available only to growers who register through the website and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop. Dry bulb and green onion.

pendimethalin (Prowl H₂O): PHI 45d (PHI 30d for green onions), REI 24h, Group 3. Emerged weeds will not be controlled by Prowl. Dry bulb onion and dry bulb shallot:

Apply 1.5 to 3.2 pt/A. Select rate based on soil texture. See label for details. Can be used preemergence after planting but before crop emergence, after crop emergence when onions/shallots are in the 1 to 5 true leaf stage, or at both timings. For green onions, use 2 pt/A as preemergence spray or as a postemergence spray to the crop at the 2 to 3 true-leaf stage. If applied sequentially as both a preemergence and postemergence spray, applications must be separated by at least 30 days. Do not exceed 4 pt/A per year on green onions.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. For use between rows after crop establishment. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 45d, 24hr REI, Group 1. Dry bulb onions and dry bulb shallots only. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluzifop (Fusilade DX): PHI 45d, REI 12h, Group 1. Dry bulb onion only. For grass weed control only. See label to select rate based on grasses targeted for control. Allow for minimum 14 days between applications, and not to exceed 48 oz/A per year. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

oxyfluorfen (Goal 2 XL): REI 48h, Group 1. Provides early postemergence and residual control of many broadleaf weed species. For direct seeded onions, apply 2 to 4 oz/A to onions that has at least 3 fully developed true leaves. For transplanted onions, an application of up to 2 pt/A acre may be made within two days after transplanting. If less than 2 pt/A acre is applied, a second application can be made two weeks or more after transplanting. Do not exceed the maximum use rate of 2 pt/A per season.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PARSLEY AND CILANTRO

Parsley (*Petroselinum crispum*) and cilantro (*Coriandrum sativum*) both belong to the *Umbelliferae* (*Apiaceae*) family, along with several other crops including carrot, celery, fennel, dill, and parsnip. Curly leaf parsley is most often used as a garnish, whereas flat leaf parsley is more often used as an ingredient. The fresh leaves of cilantro are commonly used in Mexican, South Asian, Indian and other cuisines; the dried seeds of the same plant are known as coriander.

Types and Varieties

Cilantro and Parsley Varieties	
Cilantro	Parsley - Flat Leaf
Calypso	Peione
Caribe	Dark Green
Cruiser	Giant of Italy
Leisure	Parsley - Curly Leaf
Marino	Forest Green
Santo	Krausa
	Wega

Soil Fertility

Maintain soil pH near 6.5, and maintain P and K in the high/optimum range.

Planting

Seed is sown 1/3" deep in a well-prepared seedbed. Spacing between rows is 15"-18". Usual seeding rate is 20-40 pounds per acre (1-2 oz per 100 feet of row). Seed is slow to germinate and seedlings may take 2-3 weeks to emerge. Check older seed for germination percentage and adjust seeding rate accordingly.

Culture and Harvest

Rotate parsley and cilantro plantings each year to avoid soil-borne diseases. Multiple harvests within a year are possible with parsley. A well-maintained planting can be cut from three to five times in a season. Parsley will not overwinter. Cut leaves approximately 1" above the soil line to avoid damaging the growing point. Harvesting should begin in early July with a mid- to late April seeding date. Cilantro should be harvested before it begins to bolt, and only one harvest is possible. Sequential seedings should be made to ensure steady supply.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special

instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Bacterial leaf spot of cilantro**
(*Pseudomonas syringae* pv *coriandricola*)

The initial symptoms of bacterial leaf spot are dark, water-soaked, vein-delimited spots on leaves. The spots rapidly turn dark brown in color, remain angular in shape, and can be seen from both top and bottom sides of leaves. If disease is severe, the foliage can take on a blighted appearance when leaf spots coalesce. The disease progresses rapidly during wet weather. Cilantro crops with significant amounts of this disease will be unmarketable. The causal bacterium is host specific to cilantro and does not infect celery or parsley. The pathogen is seedborne in cilantro. Thus, infested seed is the primary means by which the pathogen gets into the cilantro production system. The bacterium can also survive many years in the soil as an opportunistic bacterium. If bacterial leaf spot has been a problem, rotate out of cilantro for several years. For both conventional and organic cilantro, the only foliar treatment available is a copper fungicide.

***Bacillus amyloliquefaciens* Strain D747 (DoubleNickel 55):** 0.25 to 3.0 lb/A; PHI 0d, REI 4, Group 44.

basic copper sulfate (Cuprofix Ultra 40 Dispers): 2.0 lb/A; PHI 0d, REI 48h, Group M1.

■ **Powdery Mildew (*Leveillula lanuginosa*)**

Disease development is favored by high humidity, moderate temperatures, and drought stress. Rain or overhead irrigation reduce disease severity. The pathogen can survive between crop cycles. Control wild and volunteer Apiaceae plants. Maintain adequate fertilizer and irrigation programs to ensure good growth. Drought stress may be lessened by mulching. Use resistant cultivars when available.

■ **Root rot (*Pythium* and *Phytophthora* species)**

These pathogens are soil-borne and most severe in cold, wet soils. Provide good soil drainage and reduce soil compaction; raised beds may be useful.

mefenoxam (Ridomil Gold SL): 1.0 to 2.0 pt/A; PHI 21d, REI 48h, Group 4.

***Trichoderma asperellum*, *T. gamsii* (Bioten^{OG}):** See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

■ **Septoria blight (*Septoria petroselini*)**

Severe disease can destroy crop quality. The pathogen is seed-borne and highly favored by rain and overhead irrigation. Start with certified, disease free seed or treat seed with hot water or fungicides. Inspect transplants before setting in the field and destroy infected plants. Rotate to crops outside of the Apiaceae family.

■ **White Mold (*Sclerotinia sclerotiorum*)**

Start with certified seed that is free from sclerotia of the pathogen. Rotate with non-host plants. Irrigate in the

morning to promote drying of soil and foliage. Soil sterilization with heat, chemicals, steam, or by biofumigation with brassica crops can reduce, but not eliminate sclerotia.

***Trichoderma asperellum*, *T. gamsii* (Bio-tam^{OG}):** See label for in-furrow, drench, and broadcast rates; REI 1h, Group NC.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ **Cabbage Looper, Imported Cabbageworm and Other Caterpillars**

For more information, see cabbage looper and imported cabbageworm in the Cabbage section. Parsley worm, the larva of the black swallowtail butterfly (*Papilio polyxenes*), may invade small plantings but are not abundant enough to reach pest status on larger plantings. Hand picking or selective insecticides provide control.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.4 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Parsley only.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28. Parsley only.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 14d, REI 12h, Bee: H, Group 1A. Not for cabbage looper.

chlorantraniliprole (Coragen): 3.5 to 5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through drip chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone. On cilantro, foliar applications only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

cyantraniliprole (Exirel): 10 to 17 oz/A loopers, 13.5 to 20.5 oz/A other caterpillars; *PHI 1d, REI 12h, Bee: H, Group 28.* Parsley only.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; *PHI 0d, REI 4h, Bee: H, Group 28.* For soil applications at planting. Parsley only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.*

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Cabbage looper only. Apply when larvae are first observed.

flubendiamide (Belt SC): 1.5 oz/A; *PHI 1d, REI 12h, Bee: L, Group 28.* Active via ingestion.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A for CL, 3.5 to 6.0 oz/A for beet armyworm and corn earworm; *PHI 3d, REI 12h, Bee: H, Group 22.* For cabbage looper, beet armyworm and corn earworm only.

malathion (Malathion 57EC): 1 to 2 pt/A; *PHI 7d, REI 24h, Bee: H, Group 1B.* For imported cabbageworm and cabbage looper.

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 10d, REI 48h, Bee: H, Group 1A.* Parsley only.

methoxyfenozide (Intrepid 2F): 4 to 10 oz/A; *PHI 1d, REI 4h, Bee: L, Group 18.* Use lower rates when plants are small or infestations are light.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Not for imported cabbageworm. Parsley only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils. Cabbage looper only.

spinetoram (Radiant SC): 5 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.*

spinosad (Entrust SC^{OG}): 1.5 to 8 oz/A parsley, 4 to 6 oz/A cilantro; *PHI 1d, REI 4h, Bee: M, Group 5.* See label for recommended rates for different caterpillar species.

tebufenozide (Confirm 2F): 6 to 8 oz/A; *PHI 7d, REI 4h, Bee: L, Group 18.* Use low rate for early season applications to young, small plants. Use of an adjuvant is recommended. Parsley only.

tolfenpyrad (Torac): 21 oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A.* Suppression of caterpillars only. Parsley only.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A for ICW; 3.4 to 4.3 oz/A for CL; *PHI 1d, REI 12h, Bee: H, Group 3A.*

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and

special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107. In place of herbicides, flaming can also be used.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): *REI 12h, Group 8.* Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours of application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

■ Herbicides Used Pre- and Postemergence to Weeds

linuron (Lorox DF): *PHI 30d for parsley, PHI 21d for cilantro, REI 4d for hand-set irrigation activity and REI 24h for all other activities, Group 7.* Can be used preemergence or postemergence. Best results are obtained when application is made to moist soil (applied after at least 1/2 inch of rain or irrigation). Moisture is needed to activate Lorox, and applications should be followed by rainfall or irrigation.

For parsley, do not exceed a total of 3 lb/A per season.

- **Parsley Preemergence:** For mineral and muck soils, make a single broadcast application of 1 to 3 lb/A after planting, but before the crop emerges. Plant seeds at least 1/2 inch deep. Use lower rates on coarse soils and higher rates on heavier soils (soils high in clay and organic matter). Irrigation or rainfall of at least 1/2 inch prior to making application after planting is necessary for product activation.
- **Parsley Postemergence (Muck Soils Only):** Make a single application of 1 lb/A to control emerged weeds. Apply after parsley has a minimum of 3 true leaves or crop injury may result. Apply when weeds are in the 1 to 3 true leaf stage.

For cilantro, varieties may vary in their susceptibility to injury from Lorox. Determine tolerance to Lorox prior to adoption as a field practice to prevent possible crop injury. Do not exceed a total of 4 lb/A per season.

- **Cilantro Preemergence:** Make a single broadcast application of 1 to 2 lb/A after planting, but before the crop emerges. Plant seeds at least 1/2 inch deep. Use lower rates on coarse soils and higher rates on heavier soils (soils high in clay and organic matter). Additional postemergence applications may be made as long as the total does not exceed the seasonal maximum.
- **Cilantro Postemergence:** Make up to two postemergence applications of 1-2 lb/A to control emerged weeds. Apply after cilantro has a minimum of 3 true leaves or crop

injury may result. Apply when weeds are in the 1 to 3 true leaf stage. Early crop injury can occur, however the effect should be transitory, with no yield losses attributable to crop injury. A second application may be made 14 days following the first application but no later than 21 days before harvest.

prometryn (Caparol 4L): PHI 30d, REI 12h, Group 5. Primarily controls annual broadleaf weeds. Annual grasses may only be suppressed. Use the lower rates on coarse-textured soils and soils low in organic matter; use the higher rates on fine-textured soils and soils high in organic matter. To avoid crop injury, do not use on sand or loamy sand soils, or apply if crop is under water stress.

For parsley, can be applied pre- and postemergence. Do not exceed a seasonal maximum of 3 lb/A. Make a single preemergence broadcast application of Caparol up to 14 days after planting (after seeding, but before crop emergence) at the rate of 1.0 pt/A. Follow with overhead irrigation if rainfall does not occur.

For extended weed control, a second postemergence application can be made at 1.0 pt/A up to 30 days prior to harvest. A third application at 1.0 pt/A can be made to the regrowth up to 30 days prior to the second (cutting) harvest. Do not make more than 3 application per year at a maximum of 1 pt/A per application.

For cilantro, use preemergence only. Make a single application of 2-3.2 pt/A of Caparol after seeding, but before cilantro emergence. Use the lower rates on coarse-textured soils and soils low in organic matter; use the higher rates on fine-textured soils and soils high in organic matter.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 14d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will

cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 15d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PEA

Pea (*Pisum sativum*) belongs to the legume family. It is a cool season crop that may be planted as early in the spring as the soil becomes tillable. Field pea is commonly grown as a cover crop, or, in more arid regions, for its smooth dried seeds used as food or feed crops. Garden pea is more commonly grown in New England for fresh market use. Garden peas contain higher sugar and lower starch contents than field peas and have wrinkled mature seeds.

Types and Varieties

Three types of garden peas are in demand, all of which come in dwarf and tall vining forms:

- English Pea- only the seed is eaten.
- Snow or Edible-Podded Pea- the pod is eaten with undeveloped seeds.
- Sugar Pea or Sugar Snap- both pod and seed are eaten.

PEA Varieties	
English Pea Strike (49) - F Premium (51) - F Penelope (59) - F, PEV, PM Knight (62) - CW, PM, PEV Progress #9 (62) Maxigolt (62) Green Arrow (65) Lincoln (67) - CW Wando (68)	Snow Pea Oregon Giant (60) Avalanche (60) Blizzard (61) Oregon Sugar Pod 2 (65) - CW, PM, PEV Sugar Snap Pea Sugar Ann (52) Sugar Spring (58) - PM, PEV Sugar Snap (62) Super Sugar Snap (66) - PM, PLR
<small>The number in parentheses is the approximate number of days to maturity from seeding. Resistant or tolerant to: CW: common wilt, DM: downy mildew, F: Fusarium wilt, PEV: pea enation virus, PLR: pea leaf roll virus, PM: powdery mildew</small>	

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8.

Most research suggests that 20-30 lb of nitrogen per acre should be available at planting time, but that higher levels are not helpful. Peas can fix anywhere from 50 to 300 lbs. of nitrogen per acre, depending on plant density and availability of the appropriate species of *Rhizobium* bacteria. These bacteria, if present, live in root nodules of legumes, including peas, and convert atmospheric nitrogen into forms available

to plants (nitrogen fixation). Nitrogen obtained in this manner is used more effectively than applied nitrogen. Therefore, plant vigor and production may be higher when the seed is inoculated with the appropriate species of *Rhizobium* bacterium. Inoculant can be purchased from most seed companies and should be listed in their catalogs. It is usually applied by mixing it with the seed at planting time. Pea inoculants are the same as those for vetches and lentils. Those used for alfalfa, beans or clovers will not work with peas. If peas or vetch have recently been grown in the field, inoculation may not be necessary. Note that many seed treatments may be toxic to the bacteria.

Nitrogen fixing can be slow in a cool, wet spring, so there may not be adequate nitrogen for high yields through nitrogen fixing alone. In this case, additional nitrogen may help to increase yields. However, applying excess nitrogen may reduce bacterial nitrogen fixation. If *Rhizobium* is not present, if leaching has occurred, or for early peas, sidedressing with an additional 25 lbs of nitrogen per acre may be beneficial.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Seeding rates for peas vary considerably depending on the size of the seed. For fresh market, peas should be spaced 1.5"-2" between seeds and 24"-36" between rows at a seeding rate of 90-150 lb/A (about 1 lb per 100 feet of row).

For processing peas, seed 200-250 lb/A at 1" between plants and 7" between rows.

Field Culture

Pea seed will germinate well at soil temperatures as low as 50°F, but germination is slow. Extended periods of cool, wet weather during the germination period may cause rotting of the seed. For this reason, fertile, well-drained, sandy soils are best for early plantings. Finer-textured soils with high moisture-holding capacities are preferred for late spring crops. The use of treated seed is helpful in overcoming the problem of seed decay.

Several root rot organisms that attack peas usually begin at the tips of the feeder roots and progress towards the main roots, or occasionally show on the stem slightly above ground level. Rotation can reduce problems with root rot in peas.

Peas that mature during hot, dry weather frequently show reduced yield and quality. If hot, dry conditions normally occur in your area, pea planting should be suspended in mid-May and resume in July for fall harvest. If hot, dry summer

weather occurs for only short periods in your area, plantings can be made throughout the summer using heat-resistant varieties for mid-summer harvest.

Trellising

A trellis should be installed at the time of planting. Nylon mesh netting using twister bands to attach to 2" x 2" stakes makes a good trellis for tall varieties. At least a 6' high trellis is needed for all vining varieties. A double row can be planted for more efficient use of netting.

Harvest and Storage

Pods of shell peas should be rounded and still have a glossy sheen; if dull, they have passed their prime. Snap peas should also be glossy, and swelled, but not rounded. Pods of snow peas should be expanded to their fullest extent but still be flat. Peas should be stored at 32°F with 95-98% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Damping-Off, Seed Decay, Root Rot, and Stem Canker

Plant early in well-drained and well-fertilized soil. Use a 3- to 4-year rotation.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel LC^{OG}):** 0.5 to 4.5 pt/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

fludioxonil (Maxim 4FS): 0.8 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi.

mefenoxam (Apron XL): 0.16 to 0.64 fl oz/100 lb seed; REI 48h, Group 4. For Pythium damping-off. Early season Phytophthora protection (0.64 fl oz/100 lb seed), and systemic downy mildew protection (1.28 fl oz/100 lb seed).

***Streptomyces lydicus* strain WYEC (Actinovate AG^{OG}):** 3 to 12 oz/A; Group NC. Can be applied to seed.

***Trichoderma harzianum* Rifai strain T-22 (Root Shield Granules^{OG}):** 5 to 12.0 lb/A; Group NC. In-furrow at time of planting.

Plant Nutrient Recommendation According to Soil Test Results for Pea

PEA	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast/Planter	50-75	150	100	25-50	0	150	100	50	0
TOTAL RECOMMENDED	50-75	150	100	25-50	0	150	100	50	0

■ *Rhizoctonia* root rot and stem canker

Rhizoctonia stem canker caused by strains of the soil-borne fungus *Rhizoctonia solani* is common throughout the world. The pathogen survives between crop seasons as sclerotia (survival structures), mycelium in the soil, or on or in infected plant debris. It is spread in infested soil or plant debris by wind, rain, irrigation water, and machinery. When a soil becomes infested, it remains so indefinitely. Seedlings and young plants are highly susceptible to infection and disease severity is increased by low soil temperatures and soil compaction. Seed decay and damping off can be controlled by using high-quality seed with high germination and vigor, and by practices that encourage rapid germination and emergence. Seed treatments are not effective against infections later in the season. The disease may be reduced by sowing seed as shallowly as possible in warm, moist soil. Land preparation that minimizes soil compaction and structural damage will lessen disease severity. Rotate crops with a cereal or pasture crop (avoid beets, beans, brassicas and potatoes which increase inoculum). Cover crops and other practices that to increase organic matter and improve soil structure are recommended. Some brassica crops (mustard, rape) used as green manure have been reported to be disease suppressive. Avoid incorporating green manure immediately before planting and damaging roots by shallow cultivation. Fungicides can manage *Rhizoctonia* root rot on young seedlings if applied as a seed treatment or soil drench.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Corn Earworm (*Helicoverpa zea*) and Fall Armyworm (*Spodoptera frugiperda*)

Generally, these are late-season pests and are likely to only be a problem in fall peas. For more information, see Sweet Corn section.

alpha-cypermethrin (Fastac* EC): 2.7 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, PHI 21d dried, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OG}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. For FAW only. Use alone to control light populations, or first and second instar larvae. Add a contact insecticide to control more mature FAW larvae and higher populations. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high

rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

Bacillus thuringiensis kurstaki (Dipel DF^{OG}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Use alone to control light populations, or first and second instar larvae. Add a contact insecticide to control more mature FAW larvae and higher populations. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d fresh, PHI 14d dry, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 0.5 to 1.5 qt/A; PHI 3d fresh; PHI 21d dry, REI 12h, Bee: H, Group 1A. Use high rate for fall armyworm.

chlorantraniliprole (Coragen): 5-7.5 oz/A soil at planting, 3.5-7.5 oz/A foliar; PHI 1d, REI 4h, Bee: L, Group 28.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 7d edible-podded and succulent shelled, PHI 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d fresh, PHI 21d dry, REI 12h, Bee: H, Group 3A. Not for armyworm on dry peas.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d fresh; PHI 21d dry, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 22. Dry Southern peas only.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d fresh, PHI 21d dry, REI 24h, Bee: H, Group 3A. Use higher rates for large FAW larvae.

methoxyfenozide (Intrepid 2F): 4 to 16 oz/A for FAW, 10 to 16 oz/A for CEW; PHI 7d, REI 4h, Bee: L, Group 18. Use lower rates for FAW when plants are small or infestations are light. CEW suppression only.

spinetoram (Radiant SC): 4 to 8 oz/A; PHI 3d fresh, PHI 21d dry, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 4 to 6 oz/A; PHI 3d, REI 4h, Bee: M, Group 5.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d fresh, PHI 21d dry, REI 12h, Bee: H, Group 3A.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed on stems after dark. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Synthetic pyrethroids (Group 3A) may work best during cool spring weather. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; PHI 1d succulent shelled or edible-podded, PHI 21d dried, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d fresh, PHI 14d dry, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 to 1.5 qt/A; PHI 3d fresh, PHI 21d dry, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 5 to 8 oz/A; PHI 7d edible-podded and succulent shelled, PHI 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d fresh, PHI 21d dry, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.7 oz/A; PHI 7d, REI 24, Bee: H, Group 3. Climbing cutworm only.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 7d fresh; PHI 21d dry, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; PHI 7d fresh, PHI 21d dry, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. For variegated cutworm only.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 3d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d fresh, PHI 21d dry, REI 12h, Bee: H, Group 3A.

■ Pea Aphid (*Acyrtosiphon pisum*)

The pea aphid is light green with unusually long legs and cornicles (tailpipe-like projections). It is the primary aphid that attacks peas, fava beans and lentils. This aphid overwinters as an egg on alfalfa, vetch, and clover and moves to peas in the spring. Live female nymphs are produced throughout most of the year. Females take 12 days to mature and produce up to 150 nymphs. There are from 13 to 20 generations per year. Populations tend to be lower after cold, snowless winters or springs with persistent wet weather. Infestations during the bloom and early pod stages will reduce yield and crop quality by removing plant sap, impairing pod appearance, reducing seed fill, impairing nitrogen fixation and by the presence of aphid honeydew. Start monitoring when plants begin to flower. Action thresholds include 1 to 2 aphids per leaf, 2 to 3 aphids per stem tip or 9 to 13 per sweep, if a sweep net is being used. Harvest or spray nearby alfalfa, vetch or clover before winged adults are formed in the spring. Varieties differ in their susceptibility to pea aphid damage. Plant varieties less prone to high infestations and damage. There are many natural enemies (lady beetles, lacewings, flower fly larvae, predatory midges, Braconid wasps) that help reduce aphid numbers. Fungi will control high aphid populations during warm, humid or wet weather. A single systemic insecticide application will control this pest.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A. Not for dry peas.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 3d fresh, PHI 14d dry, REI 12h, Bee: H, Group 3A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 10 oz/A; PHI 7d edible-podded and succulent shelled, PHI 21d dried shelled, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

dimethoate (Dimethoate 4EC): 0.3 pt/A; PHI 0d, REI 48h, Bee: H, Group 1B.

esfenvalerate (Asana* XL): 2.9 to 5.8 oz/A; PHI 3d fresh, PHI 21d dry, REI 12h, Bee: H, Group 3A.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d fresh; PHI 21d dry, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A foliar, 7 to 10.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. Repeated applications or the addition of another insecticide may be necessary.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d fresh, PHI 21d dry, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57 EC): 1.5 to 1.6 pt/A; PHI 3d, REI 12h, Bee: H, Group 1B.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

thiamethoxam (Cruiser 5FS): 1.28 oz/100 lb seed; REI 12h, Bee: H, Group 4A. Systemic seed treatment. Use standard slurry seed treatment equipment which provides uniform coverage. For early-season protection from aphids.

■ Seedcorn Maggot (*Delia platura*)

See seedcorn maggot in the Bean section for more information.

chlorpyrifos (Lorsban* 4E): 2 pt/A pre-plant, 1.8 oz/1000 row ft at-plant; REI 24h, Bee: H, Group 1B. Preplant broadcast application incorporated into top 1" to 3" of soil or at-plant T band application incorporated into 1/2 to 1" of soil.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

clomazone (Command 3ME): REI 12h, Group 13. Apply 1.3 pt/A to the soil surface prior to seeding or transplanting, or after seeding but prior to crop emergence. Place seed, or roots of the transplants, below the chemical barrier when planting. Will control annual grasses and many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for replanting restrictions.

linuron (Lorox DF): REI 24h, Group 7. Make a single application of up to 2 lbs/A after planting but prior to crop emergence. Use lower rates on coarse soils and higher rates on heavier soils.

s-metolachlor (Dual Magnum): REI 12h, Group 15. English peas and dry peas. Apply either preplant incorporated or to the soil surface just after seeding. See label for specific rates on different soil types and organic matter content (1 to 2 pt/A). NOTE: If soil is cold and wet during pea germination/emergence, use of Dual Magnum can delay maturity and reduce yield.

pendimethalin (Prowl H₂O): REI 24h, Group 3. Apply 2 to 3 pt/A preplant and incorporate into the soil 2" to 3". Do not apply after seeding. Rainfall or irrigation is required for activation.

trifluralin (Treflan HFP): REI 12h, Group 3. Incorporate 1 to 1.5 pt/A before planting. Select rate based on soil texture; see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Especially effective for annual grass.

■ Herbicides Used Pre- and Postemergence to Weeds

imazethapyr (Pursuit): PHI 30d, REI 4h, Group 2. English peas and dry peas. Apply up to 3 oz/A as a preplant incorporated (with 1 week of planting) or as a preemergence up to 3 days after planting.

Can also be used early Postemergence: Apply to dry peas and English pea when peas are 3" tall but before 5 nodes and before flowering. Nonionic surfactant must be added to the spray solution for post emergence use.

■ Herbicides Used Postemergence to Weeds

bentazon (Basagran): PHI 10d, REI 48h, Group 6. Used postemergence on actively growing weeds. Rate varies based on weed species targeted (1 to 2 pt/A). Peas are tolerant to after 3 pairs of leaves (or 4 nodes) are present. Pea injury such as yellowing, bronzing, speckling or burning of leaves may occur under certain conditions. Temporary injury is generally outgrown without delay of podset, maturity or reducing yields. An effective treatment in an emergency situation to control certain broadleaf

weeds and fairly effective against yellow nutsedge when 4" to 6" tall. Do not apply when peas are in bloom or under stress from root rot. Do not add oil for use on peas.

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 21d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. A single application of 9 to 16 oz/A is permitted. Apply before bloom. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

quizalofop (Assure II): PHI 60d dry peas, PHI 30d succulent peas, REI 12h, Group 1. Apply to actively growing grasses. Rate based on target weed species, see label for grass growth stage and rate selection. Multiple applications permitted. Allow at least 7 days between applications. Do not exceed 14 oz/A per season. Apply with either crop oil concentrate or non-ionic surfactant. Do not apply when crop or weeds are under drought stress.

sethoxydim (Poast): PHI 30d dry peas, PHI 15d succulent peas, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 4 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PEPPER

Pepper (*Capsicum annuum*, *C. chinense*; Family *Solanaceae*) is a warm-season crop requiring 3-4 months of frost-free growing days. It is started from transplants. Bell peppers are the most commonly grown and are usually harvested green.

Fruits left to mature on the plant turn red, orange or yellow, and sugar content increases markedly. Other types of sweet and chili (hot or pungent) peppers are usually elongated and tapered. Hot peppers generally become more pungent as they mature or if grown under stress. Check variety descriptions carefully to obtain the proper peppers for your markets.

Types and Varieties

Pepper Varieties	
Sweet Bell - Green to Red Alliance - BLS1235, CMV, P, PVY Archimedes - BLS123, P Brigadier - BLS123, PVY Intruder - BLS123, P, TMV, TEV King Arthur - BLS2, PVY, ToMV New Ace - TMV Northstar - TMV Olympus - BLS123 Paladin - BLS123, P, TMV, TEV Patriot - BLS1235, PVY PS0994-1819 - BLS12345 Red Knight - BLS123, PVY Revolution - BLS1235, CMV, P Socrates X3R - BLS123, PVY Vivaldi - TMV X3R Camelot - BLS123, TMV	Hot - Ancho Sequoia Tiburon Ventura
	Hot - Cherry Large Red Cherry
	Hot - Banana Hot Spot X3R - BLS123 Hungarian Yellow (or Hot) Wax Inferno
	Hot - Jalapeno Conchos El Rey - BLS123 Mitla
Sweet Bell - Green to Yellow Admiral Early Sunsatation - BLS123, PVY, TMV Gloria - TMV Lafayette - BLS123, PVY	Hot - Miscellaneous Andy Habanero Hot Portugal NuMex Joe E. Parker Serrano del Sol Super Cayenne Super Chili
	Sweet Italian/Cubanelle Biscayne Carmen Cornito Giallo Cortes Escamillo Key Largo Pageant - BLS123
Resistant or tolerant to: BLS: Bacterial Leaf Spot (races indicated); CMV: Cucumber mosaic virus, P: Phytophthora crown rot, PVY: Potato virus Y, TEV: Tobacco etch virus, TMV: Tobacco mosaic virus, ToMV: Tomato mosaic virus.	

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8. Side-dress N can also be applied through a drip irrigation system over the course of the remainder of the season. This is particularly advantageous in soils prone to

leaching. See Fertigation, page 30, for more information. Excess nitrogen has been shown to reduce yields. A pre-sidedress nitrate test (PSNT) can advise on the need for sidedress nitrogen.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Growers should produce their own transplants or contract with a reputable local supplier to minimize the potential of importing severe disease and insect problems that are common in other regions. Sow seeds 8 weeks before field transplanting. Peppers are a slow-growing crop and need protection from soil-borne diseases, especially damping-off organisms. Use seed treated with a suitable fungicide or use a biofungicide soil drench (See Table 24, Biological Disease Control Products in the Biorational and Organic Pesticides). Avoid over-watering. Avoid contamination from the greenhouse floor by lining it with plastic, growing plants on benches, and hanging watering devices when not in use. Do not permit moisture to remain on seedlings for more than 2 or 3 hours after watering. This may require adjusting watering rates on cloudy days.

One ounce of seed will produce 3,000-5,000 plants. About 8,000-14,500 plants are required per acre, depending on your choice of spacing in the field. Seeds may be sown thickly in flats and later transferred to 72-cell trays. Peppers thrive under warm conditions. Seeds germinate best at 85°-90°F. Seedlings develop well at 75°F during the day and 65°F at night. Peppers are susceptible to transplant shock. Reduce temperature and water and increase air movement around the plants to condition them for transplanting. A precaution: overly-hardened plants are slow to recover and yields may be reduced. Plants should be set in the field after the danger of frost is over, and the soil temperature is at least 60°F. Peppers develop a shallow root system and may need watering 1 to 2 times per week, depending on the soil type. The use of plastic mulch, especially if combined with trickle irrigation, can significantly increase yields. Avoid letting the stems of transplants touch the plastic while setting. Center the transplants in holes to avoid burning stems and damaging or killing seedlings as plastic heats up. For best results 4"-8" tall plants should be transplanted on a cloudy, calm day, preferably in the late afternoon. Apply 1 cup of liquid starter fertilizer to each plant (refer to label), preferably one high in available P.

Space transplants 12"-18" apart within rows (67-100 plants per 100 feet of row) and 3 to 3.5' between rows. With double rows on plastic, set each row as far apart as the plastic

Plant Nutrient Recommendation According to Soil Test Results for Pepper

PEPPER	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast/Planter	50	150	100	25-50	0	200	150	50	0
Sidedress 2-3 Weeks after Planting	50**	0	0	0	0	0	0	0	0
Sidedress after First Fruit Set	40**	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	140	150	100	25-50	0	200	150	50	0

permits, but remember that plants can tip outward (lodge), bringing fruits in contact with bare soil. This spacing requires 8,300-14,500 plants per acre.

Some smaller pepper varieties or types produce spindly seedlings and plants that are not as sturdy as bell peppers and can lodge much more readily. Transplanting the seedling so that the cotyledons are at the soil surface (the root ball will be approximately 2" deep) will significantly decrease lodging without adversely affecting yield.

Field Culture

To improve fruit set: 1) plant several varieties reported to set under unfavorable conditions, 2) keep growth progressing uniformly, 3) do not transplant into the field too early, and 4) carefully meter the water and fertilizer.

In some windy locations, peppers may require staking to minimize lodging and sunscald. In each row of plants, drive half a tomato stake (18-24" long), 6" into the soil between every four to ten plants. Tie polyethylene strings at 8" and 16" heights as plants grow. Run string from stake to stake; first down one side of the plants, looping and tightening it around each stake, and then back on the opposite side of the plants. Leave a 3' gap in the trellis system every 50-100' to facilitate harvesting. In windy locations, it may be helpful to erect temporary windbreaks such as snow fence. Some growers have found improved production with such windbreaks in place.

Research in the Northeast has shown that pruning peppers is not profitable.

Harvest and Storage

Bell peppers normally are harvested in the green (immature) stage after the fruits have reached full size and the walls are firm and have thickened. Harvest the crop twice a week to achieve maximum yields, or every 7-10 days for maximum size. Peppers are picked by a twisting, pulling motion with part of the stem adhering to the fruit. Teaching workers the proper harvest technique can help avoid plant breakage and lodging, and extensive losses due to sunscald.

Peppers can be brushed or washed before packing. If peppers are washed, wash water temperature should be as warm or slightly warmer than that of the peppers. Cold wash water reduces the temperature of the pepper and that of the air inside the fruit cavity. This creates a partial vacuum which draws some of the wash water (and bacteria) into the fruit. This can contaminate the fruit with bacteria. There are commercial sanitizers registered for use in wash water to help prevent bacterial contamination through infiltration and control postharvest rots.

Containers used are wire-bound crates, cardboard boxes and bushel baskets. Twenty-four pounds per container is an average weight. The wholesale market prefers large peppers (75 or less in a 1 1/9 bu. box).

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical

Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

PESTICIDE USE IN GREENHOUSES AND HIGH TUNNELS:

Pesticides can be used on high tunnel and greenhouse crops if: 1) the crop and pest/disease is on the label, AND the products specifically says it can be used in the greenhouse; OR 2) the crop and pest/disease is on the label, AND the product is 'silent' about use in the greenhouse in the greenhouse. Products that specifically prohibit greenhouse use cannot be used in greenhouses or high tunnels regardless of the crops or pests/diseases listed on the label.

Management practices that will reduce disease in greenhouses and high tunnels are: the use of resistant varieties, sanitation, fungicides and cultural practices that keep the humidity below 90%.

See also: Table 19: Fungicides and Bactericides Labeled for Vegetable Bedding Plants, page 54.

■ Anthracnose (*Colletotrichum coccodes*)

Primarily a pathogen of ripe fruit, anthracnose occurs on fruit that is left on the plant for a long period of time. The disease is most common on red peppers that have a long ripening period. Latent infections can occur on immature fruit. The pathogen can be seed-borne and survives in the soil through the production of sclerotia. Rotate away from solanaceous plants for at least 2 years. Start with certified, disease-free seed and transplants. Plant in well-drained fields. Control solanaceous weeds. Some resistant cultivars are available. Apply fungicides preventively where anthracnose has been a problem. See fungicides below.

■ Anthracnose (*Colletotrichum acutatum*)

Anthracnose caused by *Colletotrichum acutatum* is relatively new to the pepper industry in the U.S. It is fairly widespread in the south and has occurred for consecutive years in several New England states. Unlike *C. coccodes*, this species attacks fruit of all ages and is very aggressive. During favorable weather conditions, significant losses to peppers can occur. Do not plant peppers in the same area following disease for at least 1 year. Remove all diseased plant material from the field. Most peppers are susceptible but North Star and Paladin were the least susceptible in one report. Cabrio has performed better than Quadris for this disease.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides.

azoxystrobin plus difenoconazole (Quadris Top): 8.0 to 14.0 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

chlorothalonil (Bravo Weather Stik): 1.5 pt/A; PHI 3d, REI 12h, Group M5.

copper hydroxide (Kocide 3000): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

cymoxanil plus chlorothalonil (Ariston): 2.0 to 2.44 pt/A; PHI 3d, REI 12h, Groups 27 & M3.

difenaconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 fl oz/A; PHI 70d, REI 12h, Groups 3 & 7.

Crops

famoxadone plus cymoxanil (Tanos): 8.0 to 10.0 oz/A; PHI 3d, REI 12h, Group 11 & 27. Tank mix with an appropriate contact fungicide.

flutriafol (Rhyme): 7.0 fl oz/A; PHI 0d, REI 12h, Group M3.

fluxapyroxad plus propiconazole (Priaxor): 4.0 to 8.0 fl oz/A; PHI 0d, REI 12, Groups 7 & 11.

mancozeb (Dithane F45): 1.2 to 2.4 lb/A; PHI 7d, REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; PHI 7d, REI 48h, Groups M3 & M1.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; PHI 0d, REI 12h, Group 11. Rotate to a non-Group 11 fungicide after 1 application.

tetraconazole (Mettle 125ME): 6.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Group 3. Rotate to a non-Group 3 fungicide after 2 applications.

trifloxystrobin (Flint Extra): 3.0 to 3.8 fl oz/A; PHI 3d, REI 12h, Group 11.

■ Damping Off and Seed Decay

Do not allow growing medium to remain wet. Maintain ventilation. Do not use unpasteurized growing media. Keep tools and hose nozzles clean. Do not use treated seed for food, feed or oil purposes.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lb seed; REI 48h, Group 4. Do not apply a preplant or at plant application of products containing mefenoxam.

propamocarb HCl (Previcur Flex): 1.2 pt/A; PHI 5d, REI 12h, Group 28. *Pythium* and *Phytophthora* damping-off. For greenhouse or high tunnel use see label.

■ *Phytophthora capsici* Crown Rot and Blight

Avoid planting into soils that are known to be contaminated with *Phytophthora capsici*. *P. capsici* can survive in the soil for many years; a 3-year or longer rotation with plants other than pepper, tomato, eggplant, cucurbits, or legumes may help reduce losses. If planting into infested soils, subsoil to improve drainage, use resistant varieties, and plant on raised beds shaped so they are domed in the center and shed water. Break beds to allow water to leave field through lowest paths: do not let water pool or stand around plants. Avoid bringing *Phytophthora* contaminated soil into clean or fumigated fields on farm equipment. Avoid planting low, wet areas with susceptible crops. Do not throw rotting host crops purchased off-farm on fields, or into compost piles for use on fields. Work contaminated fields last and hose down equipment before returning to non-infested fields. Alternating between two or more soil-applied fungicides, beginning at planting, and continuing throughout the season, has been shown to be more effective than foliar applications. Several products are labeled for drench or trickle applications. See label rates and directions.

For crown and stem rot:

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 4d, REI 12h, Groups 45 & 40. Labeled for foliar, soil and drip applications.

***Bacillus subtilis* Strain Strain QST 713 (Serenade Soil^{OG}):** 2 to 6 qt/A; PHI 0d, REI 4, Group 44. Apply Serenade Soil as an in-furrow spray in 5-15 gallons of water at planting.

cyazofamid (Ranman): 2.75 oz/A; PHI 0d, REI 12h, Group 21. Labeled for foliar, soil drench or overhead irrigation application.

dimethomorph (Forum): 6 oz/A; PHI 0d, REI 12h, Group 40. Suppression only. Must be applied as a tank mix with another fungicide with a different mode of action. Do not make more than 2 consecutive applications of Forum before alternating to a non-Group 40 fungicide.

fluopicolide (Presidio): 3 to 4 fl oz/A; PHI 2d, REI 12h, Group 43. Must be applied in a tank mix with another labeled fungicide with a different mode of action. Labeled for foliar, soil and drip applications.

mefenoxam (Ridomil Gold SL): 1 pt/A; PHI 7d, REI 48h, Group 4. Apply as banded spray after transplant, see label. Ridomil may cause yellowing of pepper leaves especially if soil applications are made when the soil is dry. See label for plant back restrictions and precautions. Does not control foliar/fruit phase. Resistance is a common problem.

oxathiapiprolin (Orondis Gold 200): 2.4 to 19.2 fl oz/A; PHI 0d, REI 4h, Group 49. Apply at planting in furrow, in transplant water, or by drip irrigation.

phosphorous acid (ProPhyt): 4 pt/100 gal to transplants prior to transplanting, or 5 fl oz/1000 row ft as in-furrow drench at planting; PHI 0d, REI 4, Group 33.

***Streptomyces lydicus* strain WYEC (Actinovate AG^{OG}):** 3 to 12 oz/A; Group NC. See label.

For foliar and fruit rot:

famoxadone plus cymoxanil (Tanos): 8 to 10 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Disease suppression of foliar and fruit phase ONLY. Rotate with an appropriate fungicide with a different mode of action. Must be tank-mixed with a contact fungicide.

mefenoxam plus copper (Ridomil Gold/Copper): PHI 7d, REI 48h, Groups 4 & M1. See label for rates and restrictions.

oxathiapiprolin plus mandipropamid (Orondis Gold 200): 5.5 to 8.0 fl oz/A; PHI 0d, REI 4h, Groups 49 & 40. Begin prior to disease development.

phosphorous acid (ProPhyt): 6 pt/A; PHI 0d, REI 4, Group 33.

***Streptomyces lydicus* strain WYEC (Actinovate AG^{OG}):** 3 to 12 oz/A; Group NC. See label.

■ Bacterial Canker (*Clavibacter michiganense* pv. *michiganense*)

Traditionally a tomato disease, bacterial canker can now also infect peppers and arrives on infected seed. Damage appears as irregular-shaped brown leaf spots, defoliation, and an occasional tiny, round, brown fruit spot with a white center. Foliar damage resembles bacterial spot or paraquat injury symptoms. Management is similar to methods listed below for bacterial spot.

■ Bacterial Spot (*Xanthomonas campestris* pv. *vesicatoria*)

This is one of the most destructive diseases of peppers in New England. Chemical controls are often ineffective. Effective management requires rotating to fields where Solanaceous crops and weeds in the nightshade family have not existed for at least 2 years. Maintain proper nutrient levels and avoid using dolomitic (high magnesium) lime before planting peppers. Hot-water treat pepper seeds at 122°F for 25 minutes. Use disease-resistant varieties. Grow your own transplants or contract to have them grown locally. Disinfect used flats, cell-packs, bench tops, machinery, etc. with a 1:9 mix of bleach and water; rinse well with fresh water. Scout fields weekly for plants with small brown leaf spots. Work infected fields last. Do not use high pressure, air-blast sprayers which cause increased leaf infection in rows adjacent to spray alleys and spread bacterial diseases across rows. Destroy crop residue after harvest to encourage rapid decomposition.

acibenzolar-S-methyl (Actigard 50 WG): 0.33 to 0.75 oz/A; PHI 14d, REI 12 h, Group 21. Do not use on bell peppers. Actigard is a plant activator and should be applied preventatively before disease symptoms are observed.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Disease suppression only. For improved control; mix or rotate with a chemical fungicide.

***Bacillus mycoides* Isolate J (LifeGard^{OG}):** 4.5 oz/100 gal water; PHI 0d, REI 4, Group 44.

copper hydroxide (Kocide 3000): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; PHI 7d, REI 48h, Groups M3 & M1.

streptomycin (Agri-Mycin 17): 200 ppm (1 lb/100 gal); REI 12h, Group 25. Only for greenhouse use on transplants, Streptomycin cannot be used in the field. Apply when the first true leaves appear and continue every 4 to 5 days until field transplanting.

■ Cucumber Mosaic Virus (CMV)

Many different strains of this virus occur and the host range includes plants in more than 31 different families. In pepper, the symptoms can be confused with Tomato Spotted Wilt Virus (TSWV) as well as other virus diseases. The disease is spread by several species of aphids in a nonpersistent manner. Reduce weeds, especially chickweed, pokeweed and milkweeds as much as practical. Isolate pepper fields from cucurbits and *Prunus* spp. (e.g. cherry trees) which are the overwintering host of the green peach aphid, especially where there has been a history of CMV. Insecticides will not control the spread of this virus.

■ Potato Virus Y (PVY)

Potato Virus Y (PVY) has a worldwide distribution. Three main strains have been described that differ in distribution and symptomatology. Symptoms vary widely with cultivars and virus strain combinations, ranging from mild mosaic to severe foliar necrosis. One strain can cause a symptomless

current season infection that leads to next-generation infection. Primary symptoms of PVY include mottling, yellowing, leaf drop, and premature plant death. Early infections can cause stunting and a decrease in fruit set. PVY is a member of the plant virus family *Potyviridae*, the largest and most significant virus group, and has caused significant losses in agricultural, forage, and horticultural crops. Hosts include Solanaceous, Leguminous, and *Chenopodiaceae* (i.e. spinach, chard, beets) families. Infection is transmitted in a non-persistent manner by more than 25 species of aphids and may also occur mechanically by foliar contact. Long distance transport is by winged aphids. Insecticides may slow the spread of disease within a crop, but may actually increase insect probing and be counterproductive because only a few seconds of insect feeding is sufficient for virus transmission. Minimize contact disease spread by minimizing mechanical damage during cultivation, spraying, and harvest. Remove virus-infected plants. Resistant cultivars are available.

■ Tobacco and Tomato Mosaic Virus (TMV, TomMV)

Several strains of TMV exist, including the closely related tomato (TomMV) strain. Symptoms on pepper and tomato can vary considerably as will the severity of disease and the effect on yield. Either strain can be seed-borne or transferred from previously infected plant debris, weeds, transplants, other crops, or workers using tobacco products. Unlike other viruses, TMV and TomMV are easily spread from plant to plant by contact with hands and tools. Insects are not considered to be important vectors. Grow resistant varieties. Control weeds as much as practical. Do not plant susceptible peppers or tomatoes for at least two years on land that previously had TMV infected crops. Handle plants as little as possible. Do not allow workers to use tobacco products while working with plants.

■ Tomato Spotted Wilt Virus (TSWV)

Do not raise tomato, pepper, eggplant, or cauliflower transplants in the same greenhouse as ornamentals. Monitor thrips in the greenhouse and control as necessary. Resistant varieties are not available at this time. The host range for TSWV is one of the largest of any virus. Hundreds of plant species are susceptible including many commercial floriculture crops.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Green Peach Aphid (*Myzus persicae*)

Green peach aphid overwinters in the egg stage on woody plants in the *Prunus* species (peach, wild cherry, etc.), where nymphs feed in spring. Field vegetable crops are colonized in June by winged females who produce live young (nymphs), resulting in multiple generations of wingless females. Generation time from birth to reproductive adult is 1 to 2 weeks depending on temperature; each female produces 30 to 80 live young. If food quality declines, winged females develop and leave in search of new plants. In fall, both male and female winged aphids develop and return to woody plants to mate and lay eggs.

Winged green peach aphids have a black head and thorax and yellow-green abdomen. Wingless adults and nymphs are usually pale yellow-green including the cornicles (a pair of tubes near the tip of the abdomen) but may be pink. Adults reach 2 mm long. Aphids feed on leaves and excrete a sugary, sticky substance called “honeydew” which coats fruit and fosters growth of black sooty mold fungus.

Numerous crop families (including solanaceous crops, cucurbits, brassicas, spinach and chard, and carrot families), as well as broadleaf weeds, support green peach aphid. Feeding on young tissue causes curling, wilting, reduced growth, and contamination of harvested crop. The major damage caused by this aphid is the transmission of many different plant viruses. It is also a pest in greenhouses; see Vegetable Bedding Plants and Greenhouse Tomato for greenhouse management.

Aphids are usually controlled on peppers by natural predators and parasites, such as lady beetles, lacewings, spiders, syrphid fly larvae, wasps, and beneficial fungi, unless the populations of these beneficials are disrupted by chemical sprays. Preserve natural enemies by using selective/microbial pesticides for other pests whenever possible. Occasionally green peach aphid (GPA) or, less commonly, melon aphid (MA) and potato aphid (PA) populations build up and require controls. Early-season, broad-spectrum sprays will destroy beneficials and lead to aphid population buildup.

Begin to examine plants in early July for aphids and the presence of beneficial species. Spray only when aphids are increasing and building up to high numbers. Treat at 5- to 7-day intervals if aphid numbers exceed 10 per leaf before fruit set, and 5 per leaf after fruit set. Coverage of leaf underside is important. Add a spreader-sticker. Plant crops away from *Prunus* spp. Spray effectiveness may vary depending upon the species present. Reflective plastic mulch repels aphids as long as 50% of the surface area is reflective. Even black plastic mulch has been shown to reduce aphid numbers compared with bare-ground culture.

acephate (Orthene 97): 0.5 lb/A for non-bell types and 0.5 to 1 lb/A for bell types; *PHI 7d, REI 24h, Bee: H, Group 1B*. Green peach aphid only on bell types; all aphid species on non-bells.

acetamiprid (Assail 30SG): 2 to 4 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A*.

afidopyropen (Sefina): 3 fl oz/A; *PHI 0d, REI 12 h, Bee: L, Group 9D*.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M*.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28*.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; *PHI 1d, REI 4h, Bee: H, Group 28*. For soil applications at planting, drip chemigation, or soil injection. Suppression only.

dimethoate (Dimethoate 4EC): 0.5 to 0.66 pt/A; *PHI 0d, REI 48h, Bee: H, Group 1B*.

dinotefuran (Safari 20SG): 3.5 to 7 oz/100 gal; 7 to 14 oz/A; 0.16 to 0.32 oz/sq ft.; *REI 12h, Bee: H, Group 4A*. For use on transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A*. For green peach and potato aphids only. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay. Do not apply during bloom or if bees are actively foraging; *PHI 21d, REI 24, Bee: H, Group 3*.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; *PHI 0d, REI 12, Bee: L, Group 9C*. Begin applications before populations begin to build and before damage is evident. Use higher rate for building populations or dense foliage.

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; *PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D*.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*. Suppression only.

imidacloprid (Admire Pro): 7 to 14 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; *PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A*. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L*. Spray to wet all infested plant surfaces. May require repeated applications. For enhanced and residual control apply with a companion labeled aphicide.

malathion (Malathion 57 EC): 1.25 to 1.5 pt/A; *PHI 3d, REI 12h, Bee: H, Group 1B*.

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 3d, REI 48h, Bee: H, Group 1A*. Green peach aphid only.

oxamyl (Vydate* L): 2 to 4 pt/A; *PHI 7d, REI 48h, Bee: H, Group 1A*. For foliar and drip chemigation or soil injection applications.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; *PHI 0d, REI 12h, Bee: L, Group 9B*. Green peach and potato aphids only. Translaminar. Apply when aphids first appear, before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23.* Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4C.* Do not apply until after petal fall.

thiamethoxam (Actara): 2 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations. DO NOT apply as a foliar spray.

tolfenpyrad (Torac): 17 to 21 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A.*

■ Black Cutworm (*Agrotis ipsilon*)

Black cutworm is the most common of the many cutworm species that damage vegetables in New England. Adults are night-flying tan and black moths, while the caterpillars are dark-grey to black and up to 2" in length. Moths from the South arrive between March and June. Eggs are laid mostly on grasses and winter annual weeds. Certain fields tend to have a history of repeated cutworm damage. The larvae feed after dark while hiding under the soil surface adjacent to the plant stem during the day. There are 2 to 3 generations per year but only the first generation, which produces larvae in May and June, damages seedling peppers. Leaf feeding by small larvae is common and generally unimportant, as plants compensate for leaf area lost as they grow. On rare occasions, sometimes after the soil is saturated, larger larvae switch from leaf feeding to cutting stems off near the soil line.

Ground beetles, parasitic flies and wasps and other general predators help reduce populations. When peppers follow sod/hay in rotation, fall-plowing may lower cutworm populations by reducing spring egg-laying sites. Plantings on plastic mulch experience less cutworm damage, while weedy or reduced-till fields tend to suffer greater damage. Hardening seedlings before transplanting toughens stems and reduces damage.

Adults can be monitored with a yellow and white Unitrap from March through May. Trapping should begin with the earliest warm nights when daily average temperatures exceed 50°F. A catch of over 40 moths before transplanting indicates that frequent June scouting is prudent. The first cutworm damage may be expected about 375 degree-days (base 50°F) after the first early peak of moth activity. Insect development, based on temperatures near your farm, can be monitored online (www.newa.cornell.edu). Scout problem fields once or twice weekly, checking at least 100 plants for leaf feeding and cut stems, especially near field margins. Spot spray heavily damaged areas or edges of the field if 1% or 2% of the plants have been cut down. For best results, make

application between midnight and dawn while cutworms are feeding aboveground.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M.*

carbaryl (10% Sevin Granules): 20 lb/A; *PHI 3d, REI 12h, Bee: H, Group 1A.* Apply evenly over soil surface.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

methomyl (Lannate* LV): .75 to 1.5 pt/A; *PHI 3d, REI 48h, Bee: H, Group 1A.* Variegated cutworm only.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.* Bell peppers only.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; *PHI 1d, REI 4h, Bee: M, Group 5.* Spread bait on soil around plants.

tebufenozide (Confirm 2F): 6 to 16 oz/A; *PHI 7d, REI 4h, Bee: L, Group 18.* Must be ingested. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations. Use of a spreader-binder adjuvant is recommended.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ European Corn Borer (*Ostrinia nubilalis*) and Other Caterpillars

In northern New England, European corn borer (ECB) has a single flight in mid- to late summer and sprays should coincide with this flight. In southern and central New England, ECB generally does not become a pest in peppers until the appearance of the second generation in late July or August. Apply insecticides when second generation moths become active. Check state sweet corn IPM reports for flight activity, or use pheromone traps for monitoring adult flight activity. Insect development, based on temperatures near your farm, can be monitored online (www.newa.cornell.edu). Make first application 1 week after moth count equals or exceeds 7 moths per week and fruit are present on the plants. Discontinue sprays 1 week after moth counts drop below 21 moths per week. The spray interval depends on the residual period of the insecticide used as well as weather conditions and pest pressure. Use shorter spray intervals during peak flights and while pheromone trap catches exceed 150 moths per trap. Choose selective/microbial products

whenever possible to preserve beneficials and reduce the chance of aphid outbreaks. Pyrethroids may cause aphid outbreaks by eliminating their natural enemies. See Sweet Corn for more details on ECB life cycle.

Foliage feeding caterpillars such as armyworms and hornworms rarely reach pest status on peppers in New England. Tomato hornworms (*Manduca quinquemaculata*) or tobacco hornworms (*Manduca sexta*) occasionally feed in pepper, causing leaf damage and leaving bare stalks in the canopy. Fall armyworms occasionally infest pepper foliage and fruit in August and September when preferred stages of sweet corn (whorl and pre-tassel) are no longer available and pheromone traps capture more than 90 or 100 moths per week. Most products listed for European corn borer will also control these caterpillars. Orthene will not control fall armyworm. A few products are labeled for armyworms or hornworms only as noted below.

acephate (Orthene 97): 0.5 to 1 lb/A for cabbage looper and hornworm, 3/4 to 1 lb/A for ECB; *PHI 7d, REI 24h, Bee: H, Group 1B*. Bell type only. Maintain a 7 to 14-day spray schedule during ECB flight.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11*. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A hornworm, 1 to 2 lb/A armyworm, 0.5 to 1 lb/A other caterpillars; *PHI 0d, REI 4h, Bee: L, Group 11*. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A*.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A*.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28*.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M*.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; *PHI 1d, REI 4h, Bee: L, Group 28*. May be applied to soil at planting, through chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M*.

cryolite (Prokil Cryolite): 8 to 16 lb/A; *PHI 14d, REI 12h, Bee: L, Group UN*. For armyworm, cabbage looper, hornworm.

cyantraniliprole (Exirel): 7 to 13.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28*.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 5 to 10 oz/A chemigation; *PHI 1d, REI 4h, Bee: H, Group 28*. For soil applications at planting, drip chemigation, or soil injection. Rates vary for different species.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 4h, Bee: H, Group 28*.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

diflubenzuron (Dimilin* 25W): 4 to 8 oz/A; *PHI 7d, REI 12h, Bee: L, Group 15*. Apply when larvae are small.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6*. Apply when larvae are first observed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A*. For control of ECB and suppression of armyworms.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A for hornworm, 3.5 oz/A for other caterpillars; *PHI 3d, REI 12h, Bee: H, Group 22*. Bell peppers only.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A for hornworm, 1.3 to 1.9 oz/A for other caterpillars; *PHI 5d, REI 24h, Bee: H, Group 3A*. For ECB, apply for control before larvae bore into fruit.

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 3d, REI 48h, Bee: H, Group 1A*. Use high rate for ECB. Short residual.

methoxyfenozide (Intrepid 2F): 4 to 16 oz/A; *PHI 1d, REI 4h, Bee: L, Group 18*. Must be ingested, ensure good coverage. Maintain a 7 to 14-day schedule during ECB flight. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations.

novaluron (Rimon 0.83EC): 9 to 12 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16B*.

permethrin (Pounce* 25WP): 12.8 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A*. Bell peppers only. For cabbage looper and corn earworm only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A*. Maintain a 3 to 4 day spray schedule.

spinetoram (Radiant SC): 5 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5*.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A, 4 to 8 oz/A armyworms; *PHI 1d, REI 4h, Bee: M, Group 5*. Do not apply to seedlings for transplant.

tebufenozide (Confirm 2F): 6 to 16 oz/A; *PHI 7d, REI 4h, Bee: L, Group 18*. Must be ingested. Maintain a 10 to 14-day schedule during ECB flight. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations. Use of a spreader-binder adjuvant is recommended.

zeta-cypermethrin (Mustang^{*}): 2.4 to 4.3 oz/A for ECB and hornworm; 3.4 to 4.3 oz/A for fall armyworm; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Pepper Maggot (*Zonosemata electa*)

Flies have 3 yellow stripes on back with banded wings. Maggots tunnel into the placenta (seed head) or sidewalls. Exit holes, present in late August or early September, provide entry sites for soft rot bacteria. Pepper maggots are found throughout southern New England, including southern NH. Monitor fruits of pepper plants adjacent to tree lines for oviposition (egg-laying) scars weekly during July. An oviposition scar appears as a round white scar in the middle of a shallow, indented area on the surface of the pepper fruit. Scars are particularly obvious on the high-gloss surface of cherry peppers, which can be used as indicator plants if located in outer rows along field margins. Yellow, sticky-traps baited with a vial of 28% ammonium hydroxide may be used to capture adult flies if hung in nearby trees. Traps are most reliable when hung about 20' high, within the canopy of maple trees bordering the field. Make 2 to 3 applications at 5- to 10-day intervals beginning 1 week after oviposition scars are detected or when the first fly is captured. Avoid sites with horse nettle, which serves as an alternate host. Perimeter trap cropping: spot sprays limited to cherry pepper plants in row(s) surrounding main pepper crop will control this pest and spare beneficials throughout most of the field. Note: Use of selective materials for managing ECB (IGRs, spinosad or *Bacillus thuringiensis*) will not control pepper maggots. Use of Orthene (8 to 10-day intervals) for aphids or ECB during mid- to late July and early August will control pepper maggots. The solid spinosad bait, Seduce, has produced mixed results.

alpha-cypermethrin (Fastac^{*} EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

dimethoate (Dimethoate 4EC): 0.5 to 0.66 pt/A; *PHI 0d, REI 48h, Bee: H, Group 1B.*

malathion (Malathion 57 EC): 2.5 pt/A; *PHI 3d, REI 12h, Bee: H, Group 1B.*

spinosad (GF-120 Naturalyte^{OC}): 10 to 20 oz/A; *PHI 0d, REI 4h, Bee: M, Group 5.* Begin applications as soon as monitoring indicates flies are present. Use large droplet size (4 to 6 mm) applied to lower leaf surfaces to optimize length of time bait is attractive. Use with perimeter trap cropping for best efficacy.

zeta-cypermethrin (Mustang^{*}): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Adults only.

■ Stink Bugs

See Tomato section for information on stink bugs, including Brown Marmorated Stink Bug.

beta-cyfluthrin (Baythoid^{*} 2): 1.6 to 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade^{*} 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.* Use higher rate for control of Brown Marmorated Stink Bug.

deltamethrin (Delta Gold^{*}): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

dinotefuran (Venom): 1 to 4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4A.* Foliar applications only. For brown, consperse, green, and Southern green stink bugs only. Coverage is essential for adequate control.

fenpropathrin (Danitol^{*} 2.4EC): 10.66 oz/A for all stink bugs except Brown. 7 to 10.66 oz/A Danitol 2.4EC+ 3 to 4 oz/A Belay for all stink bugs including brown, but this combination should not be applied during bloom or if bees are actively foraging; *PHI 3d Danitol alone, PHI 21d Danitol + Belay, REI 24, Bee: H, Group 3.*

gamma-cyhalothrin (Declare^{*}): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior^{*} II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

methomyl (Lannate^{*} LV): 2 to 3 pt/A; *PHI 3d, REI 48h, Bee: H, Group 1A.*

novaluron (Rimon 0.83EC): 12 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16B.*

oxamyl (Vydate L): 1.5 to 3 pints/A foliar. Apply once when insect populations are at threshold and repeat at 5-7 day intervals as needed; *PHI 7d, REI 48h, Bee: H, Group 1A.*

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

thiamethoxam (Actara): 3 to 5.5 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A.*

zeta-cypermethrin (Mustang^{*}): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* For green and brown stink bugs only. Use higher rate for brown stink bugs.

■ Thrips and Mites

These are most commonly pests in greenhouses and high tunnels. Refer to the Transplant Insect and Mite Management section for more information about greenhouse pests, including Table 18, page 51, for scouting and biological control guidelines and Table 20, page 63, about insecticides labeled for vegetable transplants in the greenhouse. Note that some of the products listed in these tables are only labeled for transplants, not crops to be sold such as greenhouse tomatoes.

abamectin (Agri-Mek^{*} SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

acequinocyl (Kanemite 15SC): 31 oz/A; *PHI 1d, REI 12h, Bee: L, Group 20B.* Two-spotted spider mite only. Do not use less than 100 gal water/A. Use of an adjuvant or surfactant is prohibited.

acetamiprid (Assail 30SG): 4 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A.* Thrips only.

alpha-cypermethrin (Fastac^{*} EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Suppression of thrips only.

beta-cyfluthrin (Baythroid^{*} XL): 2.1 to 2.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.* Thrips only.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; *PHI 3d, REI 12h, Bee: L, Group 25.* Long residual; not systemic, ensure complete coverage of upper and lower leaf surfaces and fruit. Mites only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A for thrips, 5.1 to 6.4 oz/A for mites; *PHI 7d, REI 12h, Bee: H, Group 3A.*

Chenopodium extract (Requiem EC): 2 to 4 qts/A; *PHI 0d, REI 4h, Bee: L.* Begin application as soon as thrips are seen in the crop. Thrips only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.* Suppression of thrips only.

cyantraniliprole (Verimark): 10 to 13.5 oz/A at planting, 10 oz/A chemigation; *PHI 1d, REI 4h, Bee: H, Group 28.* For soil applications at planting, drip chemigation, or soil injection.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Thrips only.

dinotefuran (Safari 20SG): 3.5 to 7 oz/100 gal; 7 to 14 oz/A; 0.16 to 0.32 oz/sq ft.; *REI 12h, Bee: H, Group 4A.* For use on transplants only, while in greenhouse. Not for use on field or greenhouse grown crops. Thrips only. Suppression only.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. Thrips only.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A Danitol 2.4EC. Two-spotted spider mite only; *PHI 3d, REI 24, Bee: H, Group 3.*

fenpyroximate (Portal XLO): 2 pt/A; *PHI 1d, REI 12h, Bee: L, Group 21A.* Mites only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.* Not for Western flower thrips. Suppression only for mites.

insecticidal soap (M-Pede^{OG}): 1.25 to 5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. Repeat applications may be needed. For enhanced and residual control apply with a companion labeled insecticide.

kaolin (Surround WP^{OG}): 12.5 to 50 lb/A or 0.125 to 0.5 lb/gal; *PHI 0d, REI 4h, Bee: L.* May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 25% of its expected harvest size. Generally compatible as a tank mix with other insecticides. For suppression and repellence of thrips only.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.* Not for Western flower thrips. Suppression only on mites.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L.*

oxamyl (Vydate* L): 2 to 4 pt/A; *PHI 7d, REI 48h, Bee: H, Group 1A.* For foliar and drip chemigation or soil injection applications. Thrips only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils. Mites only.

spinetoram (Radiant SC): 6 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Efficacy improves with the addition of an adjuvant. Thrips only.

spinosad (Entrust SC^{OG}): 4 to 8 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Do not apply to seedlings for transplant. Efficacy improves with the addition of an adjuvant. Thrips only.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; *PHI 1d, REI 12h, Bee: M, Group 23.* Effective on all developmental stages, but juvenile stages more susceptible than adults.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23.* Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility. For control of tomato russet mite and broad mite; suppression of two-spotted spider mite and thrips.

sulfoxaflor (Closer SC): 4.25 to 4.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4C.* Mites only. Suppression only. Do not apply until after petal fall.

sulfur (Microthiol Dispers^{OG}): 3 to 10 lb/A; *REI 24h, Bee: L, No IRAC classification.* Mites only.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Suppression of thrips only.

■ Whiteflies

See whiteflies in the Tomato section for more information.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A.*

afidopyropen (Sefina): 14 fl oz/A; *PHI 0d, REI 12h, Bee: L, Group 9D.*

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Suppression only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

Chenopodium extract (Requiem EC): 2 to 3 qts/A; *PHI 0d, REI 4h, Bee: L.* For silverleaf whitefly. Apply before pests reach damaging levels.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.*

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; *PHI 1d, REI 4h, Bee: H, Group 28.* For soil applications at planting, drip chemigation, or soil injection.

dinotefuran (Safari 20SG): 3.5 to 7 oz/100 gal; 7 to 14 oz/A; 0.16 to 0.32 oz/sq ft.; *REI 12h, Bee: H, Group 4A.* For use on transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; *PHI 21d, REI 24, Bee: H, Group 3.* Do not apply during bloom or if bees are actively foraging.

fenpyroximate (Portal XLO): 2 pt/A; *PHI 1d, REI 12h, Bee: L, Group 21A.*

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; *PHI 0d, REI 12, Bee: L, Group 9C.* Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage. For greenhouse whitefly suppression only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; *PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D.*

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.* Suppression only.

imidacloprid (Admire Pro): 7 to 14 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; *PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A.* Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. May require repeated applications. For enhanced and residual control apply with a companion labeled insecticide.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L.*

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; *PHI 0d, REI 12h, Bee: L, Group 9A.* Suppression only. Apply when whiteflies first appear.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

pyriproxyfen (Knack): 8 to 10 fl oz/A; *PHI 1d, REI 24h, Bee: L, Group 7.* For control of eggs and immature stages; does not control adults, but hatching of eggs laid by treated adults may be suppressed. Apply when threshold levels are reached. Translaminar.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; *PHI 1d, REI 12h, Bee: M, Group 23.* Most effective on immature stages.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23.* Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 4.25 to 4.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4C.* Do not apply until after petal fall.

thiamethoxam (Actara): 3 to 5.5 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations. DO NOT apply as a foliar spray.

WEED CONTROL

Critical Period and General Information: For optimum growth and highest pepper yields, aim to keep production areas weed-free for the first 8 to 10 weeks after transplanting until pepper plants are large enough to be competitive with weeds.

Hairy galinsoga can be an issue in pepper production fields because this weed is not controlled by most herbicides registered for use in pepper and because it resists cultivation. Stale seed beds can help by encouraging and then killing off the initial flush of germinating galinsoga seeds. If galinsoga is an issue, rotate to crops where the use of herbicides that are known to control galinsoga are permitted (such as beets where Stinger can be applied, or sweet corn where atrazine herbicides are registered for use) to help reduce the number of short-lived galinsoga seeds in the soil.

Eliminate small patches of Solanaceous weeds, such as jimsonweed and horsenettle, prior to transplanting peppers because they are in the same plant family as pepper and can serve as alternate hosts and sources for disease and insect pests.

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Use 2-4 pts/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

clomazone (Command 3ME): *REI 12h, Group 13.* Used for suppression or control of annual grass and broadleaf weeds when applied before weed emergence, including common lambsquarters, velvetleaf, and jimsonweed. Apply 0.67 to 2.67 pt/A to the soil surface prior to transplanting prior to

seeding or transplanting, or after seeding but prior to crop emergence. Place seed or roots of the transplants below the chemical barrier when planting. Use the lower rate on coarse-textured soil and the higher rate on fine-textured soil. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for rotation restrictions. Do not use on banana peppers.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.* MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. Transplanted bell pepper ONLY. This is a restricted label available only to growers who register through the website and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

napropamide (Devrinol 2-XT): *REI 12h, Group 15.* Can be broadcast applied, including use under plastic mulch, or be applied to row middles only. Apply up to 2 to 4 qt/A to a weed-free surface as preplant incorporated or as a surface spray after planting. Must be shallow incorporated or incorporated thoroughly with irrigation if adequate rainfall does not occur within 24 hours of application.

bensulide (Prefar 4E): *REI 12h, Group 8.* Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours of application. Grass control only; should be supplemented with cultivation or another registered herbicide for broadleaf control. See label for rotation restrictions.

pendimethalin (Prowl H₂O): *REI 24h, PHI 70d, Group 3.* Apply 1 to 3 pt/A, either as preplant incorporated or to the soil surface PRIOR to transplanting. If applied to the soil surface, excessive treated soil falling into the transplant hole may delay crop growth. Can be used under plastic mulch. Can also be applied as a post-directed spray on the soil at the base of the plant, beneath plants, and between rows. Avoid direct contact with foliage or stems or injury will occur. Apply before weed germination. Emerged weeds will not be controlled.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Transplants only. Incorporate 1 to 2 pt/A before transplanting. Select rate based on soil texture, see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Little or no control of ragweed, galinsoga, mustard or nutsedge. Poor weed control in soils that are wet or are subject to prolonged periods of flooding.

■ Herbicides used Pre- and Postemergence to Weeds

halosulfuron (Sanda): *PHI 30d, REI 12h, Group 2.* Apply to row middles only. Apply ½ to 1 oz/A. Will provide both preemergence and postemergence control of many weed

species. Avoid contact of the herbicide and the planted crop. If plastic is used on the planted row, adjust equipment to keep the herbicide off the plastic. Reduce rate and spray volume in proportion to the area actually sprayed. See the label for other precautions and a list of weeds controlled.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to areas between rows only with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 20d, 24hr REI, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

paraquat (Gramoxone SL 2.0*): *REI 12h, Group 22.* For use between rows after crop establishment. Apply up to 2 pt/A as a directed and shielded spray to emerged weeds between rows only when weeds are succulent and weed growth is less than 6". Maximum 3 applications per year. Use precision directed spray application equipment adjusted to prevent spray contact with crop plants. Crop contact by the spray will cause severe injury or death. Do not exceed 30 psi nozzle pressure or spray under conditions which may cause excessive drift.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): *PHI 7d, REI 12h, Group 1.* Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PHYSIOLOGICAL DISORDERS

■ Sunscald

Sunscald occurs when the pepper fruit receives too much sun. Wide plant spacing and defoliation by bacterial spot may result in sunscald. Breakage of stems by pickers will also open the plant and result in sunscald. Promote good foliage growth with proper fertilization and irrigation during prolonged periods of hot weather. Staking plants can reduce lodging and sunscald.

POTATO

Potato (*Solanum tuberosum*) is a cool season crop that produces best yields when temperatures average slightly below 70°F during the growing season. Potatoes will grow well on a wide range of soils and are especially well suited for New England. The best soil for potatoes is well-drained and medium-textured. Potatoes produced on light, sandy, loam soils generally have a more desirable shape and a brighter skin color than those grown on heavier clay-type soils. Poorly-drained soils favor disease development and may result in reduced plant stands, low yields and poor quality.

Types and Varieties

In addition to the varieties listed below, there is a good list of varieties with resistance to particular diseases in the Cornell Organic Potato Production Guide, available at: <https://ecommons.cornell.edu/bitstream/handle/1813/42897/2016-org-potatoes-NYSIPM.pdf?sequence=1>.

Soil Fertility

Lime and fertilizer should be applied according to soil test results and potato variety. If the variety is resistant to common scab, soil pH should be maintained at pH 6.0 to allow for rotation crops. If the cultivar to be raised is common scab susceptible, then the soil pH should be maintained at pH 5.0-5.2. Growers should be aware that acid scab, a scab organism that is active at low soil pH, is found in some areas; in these situations, soil pH should be raised to pH 6.0 and a scab-resistant cultivar utilized.

Nitrogen is the most critical element from the standpoint of yield and quality. Excessive nitrogen can delay maturity, decrease quality and adversely affect fry color for processing crops. Too little nitrogen will reduce yields. On most varieties, the amount of nitrogen per acre is usually 140-150

Potato Varieties	
Early-Maturing	<p>Caribe -purple-skinned, white-fleshed. Resistant to some common scab and PLRV.</p> <p>Dark Red Norland - rich dark red skin, white flesh. Tubers round to oblong. Moderately resistant to common scab, stores well.</p> <p>Irish Cobbler - buff-colored skin, white flesh. Round. Resistant to PVA, moderately resistant to blackleg and Fusarium tuber rot. Susceptible to late blight, common scab, leaf roll, potato wart, PVX; highly susceptible to PVY and Verticillium wilt.</p> <p>Satina - attractive yellow skin and flesh. Highly resistant to potato late blight and common scab. Stores well.</p> <p>Superior - buff-colored skin, white flesh. Oval. Moderately resistant to common scab.</p>
Mid-Season	<p>French Fingerling - pink skin with yellow flesh that is splashed with pink. Longer tubers than most fingerling varieties. Resistant to scab.</p> <p>Gold Rush - russet type. Resistant to hollow heart, moderately resistant to Verticillium and scab.</p> <p>Kennebec - smooth buff-colored skin with white flesh. Elliptical to long tubers. Drought tolerant, has high yield potential. Resistant to PVY and PVA, has some resistance to potato late blight and a moderate resistance to blackleg. Susceptible to Verticillium wilt and pinkeye.</p> <p>Norland - smooth red-skinned, white flesh. Moderately resistant to common scab, PVY and PLRV. Sensitive to air pollution (ozone).</p> <p>Red LaSoda - bright, deep red skin, white flesh. Round to oval tubers. Moderately resistant to early blight, tolerant to heat and drought.</p> <p>Red Pontiac - red-skinned, oblong to round tuber. Fairly drought tolerant.</p>
Late-Maturing	<p>Coastal Russet - long, slightly flattened tubers with moderately russeted skin</p> <p>Katahdin - round white cultivar, high yield potential. Has some resistance to PVY, PLRV, PVA and is tolerant of drought conditions. Susceptible to late blight, common scab.</p> <p>Russet Burbank - russeted long-tuber cultivar with high specific gravity. Resistant to common scab and blackleg. Highly susceptible to PVY.</p> <p>Russian Banana - light yellow skin, yellow flesh, banana-shaped tubers. Moderately resistant to common scab.</p> <p>Yukon Gold - yellowish, buff-colored skin, medium yellow flesh. Resistant to net necrosis and PVA, and has high specific gravity. Storability is excellent with long dormancy.</p>
Abbreviations: PVA: potato virus A, PVY: potato virus Y; PLRV: potato leafroll virus	

Plant Nutrient Recommendation According to Soil Test Results for Potato

POTATO	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Where all Fertilizer is Applied at Planting Time									
Band Placement at Planting	120-180	200	120	30-60	0-30	175	125	100	0-50
TOTAL RECOMMENDED	120-180	200	120	60	0-30	300*	250*	100	0-50
Where Sidedressing is Used									
Band Placement at Planting	80-120	200	120	30-60	0-30	175	100	50	0-50
Sidedress before plants are 6" high	40-60	0	0	0	0	125	100	50	0
TOTAL RECOMMENDED	120-180	200	120	30-60	0-30	300	200	100	0-50

*Apply 125 lb K₂O/A broadcast

pounds. Higher rates can be used on late-maturing varieties such as Russet Burbank and slightly less on early-maturing varieties such as Kennebec. Apply P and K according to soil test results.

Planting

Plant only certified or foundation seed. Certified and foundation seed has met specific conditions for production practices and disease tolerances. Planting good seed is an essential step to producing a high-quality crop.

Seed should be stored at 38°-40°F with relative humidity maintained at 95%. Seed taken from cold storage should not be planted or cut immediately. Seven to 14 days prior to cutting or planting, tubers should be warmed gradually to 50°-55°F. Good ventilation and 90% relative humidity should be maintained during this process. Cut seed pieces should be blocky, have at least one eye and weigh 1.5-2 oz.

Amount (CWT.) of Seed Needed to Plant One Acre							
34 Inch Rows				36 inch rows			
Inches between Seed in Row	Wt. of Seed Pieces (oz)	Wt. of Seed Pieces (oz)	Wt. of Seed Pieces (oz)	Inches between Seed in Row	Wt. of Seed Pieces (oz)	Wt. of Seed Pieces (oz)	Wt. of Seed Pieces (oz)
	1-1/2	1-3/4	2		1-1/2	1-3/4	2
6	29	34	39	6	27	32	37
8	22	25	29	8	20	24	27
10	17	20	23	10	16	19	22
12	14	17	19	12	14	16	18
15	11	14	16	15	11	13	14

The more uniform in size and weight the seed being planted, the more accurate the planter will perform. The ideal seedbed for planting potatoes is 50°-60°F (to encourage cut seed wound healing and rapid growth) and medium field capacity in moisture content. A well-prepared seedbed is desirable and will facilitate accurate planting. Over-preparation of the seedbed should be avoided because of crusting and compaction problems. Do not plant cut seed in soil below 45°F to avoid seed piece decay.

Suggested Seed Spacing	
Cultivar	Spacing in the Row
Kennebec	6" to 8"
Katahdin, Superior, Green Mountain and Irish Cobbler	7" to 10"
Russet Burbank, GoldRush	12" to 16"

Close spacing in the row, 6"-8", aids in reducing tuber size and increases the number of tubers set. Using close spacing can reduce the occurrence of hollow heart and growth cracks. Seed pieces should be planted 2"-4" below the soil level; this will reduce problems with sunburned tubers. For rapid emergence, no more than 2" of soil should cover the seed piece after planting. Where seed is planted deeper than 2", drag-off, or the removal of the excess soil from the top of the hill may be employed to encourage rapid emergence. Rapid emergence should be encouraged to reduce problems with soil-borne pathogens such as *Rhizoctonia*.

Green Sprouting

The practice of pre-sprouting seed potatoes is called green sprouting or chitting. This accelerates plant emergence and

speeds the development of marketable tubers, resulting in a gain of 7-10 days to marketable tubers. This practice is often combined with close plant spacing (about 6"). The tubers are harvested when small and often sold in quart baskets.

About 6 weeks prior to planting, spread whole seed tubers in open-top crates, boxes or flats, 1 layer deep with the eyes up. Egg cartons for small seed lots work great. Keep them in a warm place (approximately 70°F) in medium light intensity (bright shade). Direct sunlight is not recommended. The warmth stimulates the development of strong sprouts, which in the presence of light, will remain short and stout and will not easily be broken off during the planting process. Cut the seed into pieces when the sprouts are about 1" in length. Cutting seed pieces prior to green sprouting will dry them out and reduce quality.

Cultivation and Hilling

Hilling allows the use of a shallow planting depth to speed plant emergence, while providing the soil depth necessary later in the season for proper tuber development and protection from sunlight and adverse temperatures. Begin hilling and cultivation operations after the plants begin to emerge and complete prior to the plants filling half of the row to minimize damage to foliage. Discs, rolling cultivators, hilling listers or implements with winged cultivator teeth may be used. For best results, hills should be flat and broad rather than narrow and peaked. Cultivation during hilling aids in mechanical weed control and soil-applied herbicides can be incorporated at this time.

Sprout Inhibitors

Sprout inhibitors should be used only in conjunction with good storage management. Federal law requires that shipping containers carrying potatoes treated with postharvest sprout inhibitors be labeled with the chemical name of the inhibitor. When small bags are shipped in master containers, only the master container needs to be labeled. Do not treat seed potatoes.

Field Application: Apply 3 lb. a.i. Maleic Hydrazide/A to healthy, green, non-water-stressed potato vines at least 2 weeks before application of any vine killer. Apply when most of the tubers of Russet Burbanks are 4-6 oz in weight and Round White varieties are 1-3/4"-2" in diameter. If rain comes within 24 hours of application, effectiveness will be reduced. Do not apply at temperatures above 85°F. See label for additional information.

Postharvest Custom Applications: Bulk storage equipped with good ventilation through the pile or pallet box storages can be treated with chloro-IPC, sold under a variety of trade names, by licensed custom applicators. Application should be only after harvest cuts and bruises have healed (two to three weeks after harvest). Low doses can increase internal sprouting. Seed potatoes should not be placed in treated storage at any time. Chloro-IPC is sold as an aerosol treatment to be applied in storage or as an emulsifiable concentrate to be added to wash water for prevention of sprouting in marketing channels. Do not use the herbicide formulation for sprout control. Two other custom-applied materials are also registered. They are Amplify (diisopropylnaphtalene) and 1,4 Sight (1,4-dimethylnaphtalene).

Postharvest Application: Sprout Torch (clove oil) can be used as an aerosol or a spray to temporarily eliminate sprouts on

potatoes in storage. Do not use on stored seed potatoes. Do not allow vapors to come in contact with storage areas used for seed potatoes within 60 days of storing seed potatoes. Do not apply in the field.

Vine Desiccation

Potato vines should be desiccated approximately twenty-one days prior to harvest to ensure good skin set on tubers that are to be stored. Growers should be aware that rapid vine desiccation, whether from chemical or mechanical methods, could cause stem-end discoloration.

Mechanical desiccation practices, such as mowing or rotobating, is not recommended for seed production. Care should also be taken not to rotobeat so vigorously as to promote a *Fusarium* infection at the stolon attachment on tubers.

With chemical desiccation, rates should be reduced if potato plants are stressed. Please refer to the label of the product being used.

Please note that potato plants are susceptible to diseases and should be protected from potato late blight as long as green plant material is visible

Thorough coverage is important for all these products as they are contact herbicides. Field observations suggest the following ranking of desiccants in terms of speed of stem desiccation: paraquat (fastest) > diquat > glufosinate > endothall (slowest). This implies that the risk of stem end discoloration is greater with paraquat than with the other vine desiccants.

NOTE: ALWAYS FOLLOW LABEL INSTRUCTIONS. The information provided here is based on product labels at the time of writing. If there is any discrepancy between the label and the information below, follow label instructions. The current label for any given product is “the law” regarding its application. Also, the products listed here are based on what is currently labeled for use in the state of Maine—these products may or may not be approved for use in other jurisdictions.

carfentrazone (Aim): 3.2 to 5.8 oz/A (PHI 7d, REI 12h). Suitable for seed and storage. A spray adjuvant (NIS, MSO, or COC) is required (1 to 2% v/v). Thorough coverage is essential. A second application may be required depending on density of vine growth. A 7 to 14 day interval is recommended between applications and not more than 11.6 oz/A may be applied in one season. Minimum spray volume is 20 gal/A. May be tank mixed or used sequentially with other desiccants (refer to other product labels for restrictions).

diquat (Reglone): 1 to 2 pt/A (PHI 7d, REI 12h). Suitable for seed and storage. Always use a spray adjuvant (0.1 to 0.5% v/v NIS). Rainfast in 30 minutes. A second application may be made depending on density of vine growth. A 5 day interval is recommended between applications and not more than 4 pt/A may be applied in 1 season. Minimum spray volume of 20 gal/A.

glufosinate-ammonium (Rely): 3 pt/A (PHI 9d, REI 12h). NOT for seed. This is the same active ingredient as Liberty herbicide. Rainfast in 4 hours. Minimum spray volume of 20 gal/A.

paraquat (Firestorm or Parazone 3SL): is not registered as a vine desiccant for either storage or for seed potatoes. However, it can be used for Fresh Market Potatoes ONLY: 0.7 to 1.3 pt/A (PHI 9d, REI 24h). Potatoes must be harvested promptly after desiccation and immediately processed or consumed. Split applications may be made with a minimum of 5 days between applications. Do not apply more than 2.6 oz/A per season. Always use either NIS at 0.125% v/v (if NIS is less than 75% surface-active agent use 0.25% v/v), or COC at 1.0% v/v. Rainfast in 30 minutes. Minimum spray volume is 20 gal/A. Do not apply to drought-stressed potatoes. Application to immature potato foliage will not give complete desiccation.

pyraflufen-ethyl (Vida): 2.75 to 5.5 oz/A (PHI 7d, REI 12h). Apply when the crop is in the early stages of senescence for best results. The product may be tank-mixed in sequence with other desiccant products for improved desiccation. Minimum spray volume is 20 gal/A. Application may be repeated after 7 days but do not apply more than 11 oz/A in one season. Rainfast in 1 hour. Label suggests that it may not be effective in burning down grassy weeds.

Harvest

Premature harvesting can result in reduced yields and lower specific gravity. On the other hand, if harvesting is delayed too long, field frost and diseases can cause serious losses. Proper operation of the harvesting equipment and careful handling can reduce the amount of damage from bruising. Potatoes should not be allowed to fall more than 4"-6" and all equipment surfaces should be padded. If potatoes are harvested at temperatures below 55°F, considerable bruising is likely to occur. If tubers are harvested during hot weather (above 80°F) and they cool off slowly, the likelihood of storage rot is increased. The ideal temperature during harvest is 60°-70°F. Information on bruise testing is available from the University of Maine Cooperative Extension.

Storage

Healing of cuts and bruises is most rapid at high relative humidity (95%) with a tuber temperature of 50°-60°F and adequate through-the-pile ventilation. This temperature should be provided for 2-3 weeks at the beginning of the storage period. This process is called suberization. Effective suberization will reduce evaporative weight loss and prevent rot organisms from entering damaged tubers. After suberization the temperature should be lowered gradually to 40°F for tablestock or seed or maintained at 50°F for chip stock varieties. When a rot potential such as field frost, late blight or ring rot is present, the curing period should be eliminated, the temperature dropped and the ventilation increased. The crop should be utilized as soon as possible.

An important aspect of potato pest control is to provide a pathogen-free storage environment. All storage and potato handling equipment surfaces should be thoroughly cleaned and disinfected prior to handling and placing the crop into storage. Surfaces should be well moistened by the disinfectant spray. Spray bin walls until there is a slight runoff. Several disinfectant materials are available including quaternary ammonium compounds, (Prosan and Ster-Bac); sodium hypochlorite products (Agclor); and hydrogen dioxide products (Storox). Please consult the labels for specific directions.

Temperature control is best achieved with forced air ventilation that is controlled thermostatically by an air proportioning system. Air flows should not exceed 1.0 cu ft/cwt/min. Storage relative humidity should be as high as possible without causing condensation on the storage walls and ceilings. Good insulation properly protected with a vapor barrier reduces danger of condensation.

Pre-storage Fungicide Treatment

Treatment of potatoes (seed and tablestock) with thiabendazole (Mertect 34°F) as they go into storage has produced excellent control of *Fusarium* dry rot in storage. However, resistant isolates of *Fusarium* are now common. Preventing cuts and bruises is the best defense against this disease. Growers may consider, as an alternative, treatment of tubers going into storage with products containing mono- and di-potassium salts of phosphorus acid (Phostrol) to reduce the tuber-to-tuber spread of potato late blight and pink rot as the tubers enter storage. These chemicals should be applied uniformly in a fine mist or fog as tubers pass over a roller table or bin loader. The rolling motion will facilitate even coverage. Do not saturate the tubers.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Seed Piece Treatment (Fungi)

Potato seed treatment is one of the more overlooked portions of a whole-season disease control program. Properly suberized and properly treated seed will provide a better, more uniform stand of plants. Proper application of the appropriate material is necessary. Too much chemical may prove phytotoxic. Inadequate coverage may not totally protect the seed-piece. Dust formulations are preferable for cut seed. CAUTION: Dip treatments may spread bacteria to seed pieces which were previously not affected. NOTE: Many of these seed treatments are now formulated with Douglas fir or alder bark as a carrier. Improved healing of the cut surface has been reported with these products. Some seed treatments can be purchased combined with imidacloprid. Do not use treated seed potatoes for feed or food purposes.

azoxystrobin plus mefenoxam (Quadris Ridomil Gold SL): 0.82 fl oz/100 row feet; REI 0h, Groups 11 & 4.

Bacillus subtilis GB03 (2-3-2 Companion⁰⁶): 1.0 to 2.0 fl oz/gal; PHI 0d, REI 4h, Group NC. For seed cuttings dip. See label for additional application methods.

cymoxanil (Curzate 60 DF): 0.25 to 1.0 oz per hundred weight of cut seed pieces; REI 12h, Group 27. For tuber-borne late blight. Must be applied in a tank mix with another registered product.

fenamidone (Reason 500 SC): 0.15 fl oz/100 lb of seed pieces; REI 12h, Group 11. For seed-borne late blight. See label for application restrictions. NOTE: seed pieces may not be used for food, feed or fodder.

fludioxonil (Maxim PSP): 0.5 lb/100 lb seed-pieces; REI 12h, Group 12. Apply to cover thoroughly.

fludioxonil plus mancozeb (Maxim MZ): 0.5 lb/100 lb.; REI 24h, Groups 12 & M3.

mancozeb (Dithane F45 Rainshield): 1.6 to 2.5 fl oz/100 lb.; REI 24h, Group M3.

PCNB (Blocker 4F): 5.2 to 10.4 fl oz/1000 row ft.; REI 12h, Group 14. For *Rhizoctonia* control, apply in 10-20 gallons of water per acre based on a 34-inch row spacing. See label for other application methods and restrictions.

Trichoderma harzianum Rifai Strain KRL-AG2 (RootShield WP⁰⁶): 0.03 to 3.0 oz/100 lb seed; REI 0h, Group NC. See label for additional application methods.

Trichoderma harzianum Rifai strain T-22 and T. virens Strain G-41 (RootShield Plus WP⁰⁶): 0.03 to 3 lb/100 lb seed; REI 0h, Groups NC. For suppression of *Rhizoctonia* black scurf and stem canker. Also labeled for in-furrow application. Not effective in cool (below 50°F) and wet soils. See label for additional application methods.

■ Dickeya, Dickeya black leg (*Dickeya dianthicola*)

Dickeya dianthicola is a bacterial pathogen within the blackleg complex. In general, *Dickeya* species are transmitted via seed pieces. Infected seed potatoes are usually non-symptomatic or have non-distinctive rot symptoms. Use sound sanitation practices when handling seed pieces to prevent contamination of other potato lots. The first symptom is poor emergence (skips in a production field) due to rotting seed pieces. Plants that emerge from contaminated seed often wilt and usually have blackened stems that extend upwards from rotting seed piece. Some affected plants may only appear unthrifty. The internal stem tissue may be discolored. Rotations that contain corn followed by brassicas should be avoided prior to planting potatoes. Growers should ensure that they purchase certified seed that has been inspected for *Dickeya*. Fields where *Dickeya* has been confirmed should be avoided for the following year. No pesticides are effective for managing *Dickeya*.

■ Early Blight (*Alternaria solani*)

Crop losses can be heavy if serious defoliation occurs before or soon after flowering. Apply any of the following fungicides when plants are 4" to 6" tall. Begin applications earlier if late blight is found in your area, or if disease forecast systems recommend beginning a protection program. Repeat at 5- to 7-day intervals, depending on amount of moist weather or dew. Use a shorter interval under cool (60°F to 70°F) moist conditions. Incorporate diseased vines after harvest and avoid growing pepper, tomato, and potato in a continuous rotation. Allow tubers to mature fully before harvesting, avoid harvesting when the soil is wet, and prevent mechanical injury during harvest and handling. Proper fertilization and mineral balance will reduce susceptibility of plants to early blight. Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu).

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; *PHI 14d, REI 4h, Group 11.* Do not make more than one application of Quadris before alternating with fungicides with a different mode of action.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; *PHI 14d, REI 12h, Groups 11 & M5.* See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 8.0 to 14.0 fl oz/A; *PHI 14d, REI 12h, Groups 11 & 3.*

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; foliar application; *PHI 0d, REI 4h, Group 44.* For disease suppression only. For improved control; mix or rotate with a chemical fungicide. See label for spray volume calculations.

***Bacillus mycoides* Isolate J (LifeGard^{OG}):** 4.5 oz/100 gal water; *PHI 0d, REI 4h, Group P6.*

boscalid (Endura 70 WDG): 3.5 to 4.5 oz/A; *PHI 10d, REI 12h, Group 7.*

chlorothalonil (Bravo Weather Stik): 0.75 pt/A before vines close between rows; 1.0 to 1.5 pt/A after vines close between rows or when disease severity values are reached; *PHI 7d, REI 12h, Group M5.*

chlorothalonil plus potassium phosphite (Catamaran): 4.0 to 5.5 pt/A; *PHI 7d, REI 12h, Groups M5 & 33.*

copper hydroxide (Kocide 3000): 0.5 to 1.75 lb/A; *PHI 0d, REI 48h, Group M1.* Under severe disease, may be tank mixed with other compatible fungicides labeled for potatoes. See label for instructions.

copper oxichloride plus copper hydroxide (Badge X2^{OG}): 1.0 to 4.0 lb/A; *PHI 0d, REI 48h, Group M1.* Apply higher rate when disease is more severe. Under favorable disease conditions, can tank mix with other compatible fungicide registered for use in potatoes. See label for instructions.

Cymoxanil plus chlorothalonil (Ariston): 2 pt/A; *PHI 14d, REI 12h, Group 27 & M5.* See label for restrictions. Note longer pre harvest interval.

famoxadone plus cymoxanil (Tanos): 6.0 oz/A; *PHI 14d, REI 12h, Groups 11 & 27.* Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 to 8.2 fl oz/A; *PHI 14d, REI 12h, Group 11.* Do not rotate with other Group 11 fungicides.

fluopyram plus pyrimethanil (Luna Tranquility): 11.2 fl oz/A; *PHI 7d, REI 12h, Group 7.*

fluxapyroxad plus propiconazole (Priaxor): 4.0 to 8.0 fl oz/A; *PHI 7d, REI 12h, Groups 7 & 11.*

iprodione (Rovral 4F): 1.0 to 2.0 pt/A; *PHI 14d, REI 24h, Group 2.*

mancozeb (Dithane F45 Rainshield): 0.4 to 1.6 qt/A; *PHI 3d, REI 24h, Group M3.* See label for application instructions and restrictions. Use of Latron surfactant is recommended.

mancozeb plus copper hydroxide (ManKocide): 1.5 to 5.0 lb/A; *PHI 3d, REI 48h, Groups M3 & M1.*

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; *PHI 3d, REI 48h, Groups M3 & 22.* Addition of a spreading/penetrating type of adjuvant is recommended. Make no more than 2 consecutive applications before alternating with another fungicide with a different mode of action. 2-3 gallons of spray are generally optimum.

mandipropamid plus difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; *PHI 14d, REI 12h, Group 40 & 3.*

metconazole (Quash): 2.5 to 4.0 oz/A; *PHI 1d, REI 12h, Group 3.*

metiram (Polyram 80 DF): 1.5 to 2.0 lb/100 gal water; *PHI 3d, REI 24 h, Group M3.* See label for application instructions and restrictions.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; foliar or chemigation; *PHI 0d, REI 4h, Group 19.* See label for application instructions.

propamocarb (Previcur Flex): 0.7 to 1.2 pt/A; *PHI 14d, REI 12h, Group 28.* Must be tank mixed with a contact fungicide. See label for rates and timing.

pyraclostrobin (Headline SC): 6.0 to 9.0 fl oz/A; *PHI 3d, REI 12h, Group 11.* Do not alternate with other Group 11 fungicides.

pyraclostrobin plus metiram (Cabrio Plus): 2.0 to 2.9 lb/A; *PHI 3d, REI 24h, Group 11 & M3.*

pyrimethanil (Scala SC): 7.0 fl oz/A; *PHI 7d, REI 12h, Group 9.*

trifloxystrobin (GEM 500 SC): 2.9 to 3.8 fl oz/A; *PHI 7d, REI 12h, Group 11.*

trifenyltin hydroxide (Super Tin 80 WP): 1.8 fl oz/A; *PHI 7d, REI 48h, Group 30.*

■ Late Blight (*Phytophthora infestans*)

Late blight can occur from infected seed potatoes or infected tubers overwintered in the field. New strains of *P. infestans* introduced into the region are resistant to metalaxyl. Do not leave cull piles of potatoes in the field. The fungicides used for early blight have some protective ability against *Phytophthora* but cannot be relied on to provide significant control. If late blight is reported within 0.5 mile, begin applications of an appropriate fungicide. Disease progression throughout the US can also be monitored (www.usablight.org). Plants with significant disease should be plowed under. Check with your local extension specialist for the availability of special exemption fungicides. Disease development, based on weather conditions near your farm, can be monitored online (www.newa.cornell.edu).

ametoctradin plus dimethomorph (Zampro): 11 to 14.0 fl oz/A; *PHI 4d, REI 12h, Groups 45 & 40.*

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; *PHI 14d, REI 12h, Groups 11 & M5.* See label for tank mix precautions.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel 55^{OG}):** 0.25 to 3.0 lb/A; above ground application; *PHI 0d, REI 4h, Group 44.* Disease suppression only. For improved control; mix or rotate with a chemical fungicide. See label for other application methods and rates.

Bacillus mycooides Isolate J (LifeGard^{OC}): 4.5 oz/100 gal water; *PHI 0d, REI 4h, Group 6*. See label to determine concentration for different spray volumes (20-100 gal/A).

chlorothalonil (Bravo Weather Stik): 0.75 pt/A before vines close between rows; 1.0 to 1.5 pt/A after vines close between rows or when disease severity values are reached; *PHI 7d, REI 12h, Group M5*.

chlorothalonil plus potassium phosphite (Catamaran): 4.0 to 5.5 pt/A; *PHI 7d, REI 12h, Groups M5 & 33*. Do not apply in a solution having a pH of less than 6.5. See label for tank mix restrictions.

copper hydroxide (Kocide 3000): 0.5 to 1.75 lb/A; *PHI 0d, REI 48h, Group M1*. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette. See label for tank mix restrictions.

copper oxychloride plus copper hydroxide (Badge SC): 1.0 to 4.0 lb/A; *PHI 0d, REI 48h, Group M1*. Apply up to 4lb/A when disease is more severe. Under favorable disease conditions, can tank mix with other compatible fungicide registered for use in potatoes.

cyazofamid (Ranman 400SC): 1.4 to 2.75 fl oz/A; *PHI 7d, REI 12h, Group 21*. Do not make more than 1 application before alternating with a fungicide with a different mode of action. Addition of an organosilicone surfactant may be desirable.

cymoxanil (Curzate 60 DF): 3.2 oz/A; *PHI 14d, REI 12h, Group 27*. Use only in combination with a labeled rate of a protectant such as manzate, chlorothalonil or triphenyltin hydroxide.

cymoxanil + chlorothalonil (Ariston): 2.0 pt/A; *PHI 14d, REI 12h, Groups 27 & M5*. Must be applied in a tank mix with a fungicide with a different mode of action. Do not make more than 2 sequential applications before alternating to a non-Group M5.

dimethomorph (Forum): 4.0 to 6.0 fl oz/A; *PHI 4d, REI 12h, Group 40*. Must be applied in a tank mix with a fungicide with a different mode of action. Do not make more than 2 sequential applications before alternating to a non-Group 40 fungicide.

famoxadone plus cymoxanil (Tanos): 6.0 to 8.0 oz/A; *PHI 14d, REI 12h, Groups 11 & 27*. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500 SC): 5.5 to 8.2 fl oz/A; *PHI 14d, REI 12h, Group 11*. Do not make more than one application of Reason before alternating to a fungicide with a different mode of action.

fluzinam (Omega 500F): 5.5 fl oz/A; *PHI 14d, REI 12h, Group 29*. Must be applied in a tank mix with a fungicide with a different mode of action. Do not make more than 2 sequential applications before alternating to a non-group 40.

mancozeb (Dithane F45 Rainshield): 0.4 to 1.6 qt/A; *PHI 3d, REI 24h, Group M3*.

mancozeb plus copper hydroxide (ManKocide): 1.5 to 5.0 lb/A; *PHI 3d, REI 48h, Groups M3 & M1*.

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; *PHI 3d, REI 48h, Group M3 & 22*. Increase the use rate according to vine development.

mandipropamid plus difenconazole (Revus Top): 5.5 to 7.0 fl oz/A; *PHI 14d, REI 12h, Groups 40 & 3*. Addition of a spreading/penetrating type of adjuvant is recommended. Make no more than 2 consecutive applications before alternating with another fungicide with a different mode of action.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; *PHI 14d, REI 48h, Groups 4 & M5*.

mefenoxam plus copper (Ridomil Gold Copper): 2.0 lb/A; *PHI 14d, REI 48h, Groups 4 & M1*. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

mefenoxam plus manzate (Ridomil Gold MZ): 2.5 lb/A; *PHI 3d, REI 48h, Groups 4 & M3*. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

oxathiapiprolin plus chlorothalonil (Orondis Opti): 1.75 to 2.5 pt/A; *PHI 7d, REI 12h, Groups 49 & M5*.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; *PHI 14d, REI 4h, Groups 49 & 40*.

phosphorus acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to heat or moisture stressed plants. See label for additional precautions.

propamocarb (Previcur Flex): 0.7 to 1.2 pt/A; *PHI 14d, REI 12h, Group 28*. Must be tank mixed with a contact fungicide. See label for rates and timing.

pyraclostrobin (Headline): 6.0 to 12.0 fl oz/A; *PHI 3d, REI 12h, Group 11*. Do not rotate with other Group 11 fungicides.

pyraclostrobin plus metiram (Cabrio Plus): 2.9 lb/A; *PHI 3d, REI 24h, Group 11 & M3*.

trifloxystrobin (GEM 500 SC): 3.8 fl oz/A; *PHI 7d, REI 12h, Group 11*. Must be tank mixed with a protectant.

triphenyltin hydroxide (Super Tin 80 WP): 1.87 oz/A; *PHI 7d, REI 48h, Group 30*.

zoxamide plus chlorothalonil (Zing!): 32.0 to 34.0 fl oz/A; *PHI 7d, REI 12h, Groups 22 & M5*.

■ Common Scab (*Streptomyces* spp.)

Scab is caused by the soilborne bacterium *Streptomyces scabies*. The disease tends to be prevalent when soil is dry during tuber initiation, soil pH is above 5.2, and non-decomposed manure is used as fertilizer. Continuous cropping of potato will also increase the disease. When planting susceptible varieties, avoid fields with a history of scab. When scab is present, rotate out of potatoes for at least 2 years. Beets, carrots, radish and some weeds can also be hosts. Maintain soil pH at 5 to 5.2. The varieties Norchip, Norland, Pike, Salem and Superior are resistant to scab. Allegany, Andover, Atlantic, Chieftain, Elba, Genesee, Monoma, Reba and Redsen are moderately resistant. Katahdin, Kennebec and Snowden are moderately susceptible. Chippewa, Kanona, Norwis and Yukon Gold are very susceptible.

■ *Pythium* Leak or shell rot (*Pythium* spp.)

Leak can be a problem in stored potatoes, especially bruised, immature potatoes harvested in hot weather.

mefenoxam (Ridomil Gold SL): 0.42 oz/1,000 linear ft (in furrow); *REI 0, Group 4*. Apply as a 6-8 inch band at planting in a minimum of 3 gal of water. See label for pre-plant incorporated application rates. Can be supplemented with a phosphorous acid product. See label for details. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

mefenoxam plus chlorothalonil (Ridomil Gold Bravo SC): 2.5 pt/A; *PHI 14d, REI 48h, Groups 4 & M5*. Apply as a 6-8 inch band at planting in a minimum of 3 gal of water. Can be supplemented with a phosphorous acid product. See label for details. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

mefenoxam plus copper (Ridomil Gold Copper): 2.0 lb/A; foliar applied. *PHI 14d, REI 48h, Groups 4 & M1*. Apply as a 6-8 inch band at planting in a minimum of 3 gal of water. Can be supplemented with a phosphorous acid product. See label for details. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

mefenoxam plus manzate (Ridomil Gold MZ): 2.5 lb/A; *PHI 3d, REI 48h, Groups 4 & M3*. Apply as a 6-8 inch band at planting in a minimum of 3 gal of water. Can be supplemented with a phosphorous acid product. See label for details. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

phosphorus acid (Phostrol): 3.75 to 10 pt/A; in furrow or 2.5 to 10 pt/A foliar applied; *PHI 0d, REI 4h, Group P7*. For suppression of leak, combine the in-furrow treatment of phosphorous acid with a mefenoxam fungicide (Group 4). Additional in-season foliar applications of a phosphorous acid containing fungicide tank mixed with a mefenoxam containing fungicide may be necessary to achieve adequate control. See labels for specific rates.

■ *Verticillium* and *Fusarium* Wilt

Verticillium and *Fusarium* are soil-borne fungi that cause vascular wilts of potato. They can be introduced into fields by contaminated seed or soil. Continual potato production tends to result in an increase in wilt disease. A combination of lesion nematodes and *Verticillium* results in early death. Rotation with non-susceptible crops such as grasses will reduce disease. Destruction of infected potato vines by tillage encourages rapid decomposition and lessens the build-up of soil inoculum. At this time, there are no varieties resistant to *Fusarium* wilt. Avoid highly susceptible cultivars and start with certified, disease-free seed pieces.

***Trichoderma asperellum, T. gamsii* (Bio-tam 2.0⁰⁰):** See label for in-furrow, drench, and broadcast rates; *REI 1h, Group NC*.

■ Potato Leaf Roll Virus (PLRV)

Virus control will be enhanced by buying certified seed. Consult seed producers to determine what the certification

covers. Destroy cull piles and volunteer plants. Potato leafroll virus is the most serious virus disease of potatoes in New England and can result in significant yield reductions. The virus is transmitted by aphids in a persistent manner. The virus can overwinter in unharvested tubers which may develop into virus-infected volunteer plants. Plant virus-free, certified seed. Remove volunteer plants. Rogue plants with virus symptoms. When populations of aphids reach economic thresholds, treatment is warranted. Do not use any of last year's potato harvest for seed.

■ Potato Virus S (PVS), Potato Virus A (PVA), Potato Virus X (PVX)

Virus control will be enhanced by buying certified seed. Consult seed producers to determine what the certification covers. Destroy cull piles and volunteer plants. Do not keep potatoes for seed. These viruses may occur singly or in combination. PVY, PVS and PVA are spread by aphids in a nonpersistent manner. PVX is not known to be spread by aphids but is easily spread by plant-to-plant contact, farm machinery or cultural practices. Plant certified virus-free seed. Plant early, use resistant varieties, and control aphid populations.

■ Potato Virus Y

Potato Virus Y (PVY) has a worldwide distribution and is one of the most important viruses affecting potato. Three main strains have been described that differ in distribution and symptomatology. Symptoms vary widely with cultivars and virus strain combinations, ranging from mild mosaic to severe foliar necrosis. One strain can cause a symptomless current season infection that leads to next-generation infection. Primary symptoms of PVY include mottling, yellowing, leaf drop, and premature plant death. Potato with secondary infection exhibit stunting, mottling, stem necrosis, and crinkled leaves. Symptoms may be suppressed by low or high temperatures. Tuber symptoms generally correspond to leaf effects. PVY is the type member of the plant virus family *Potyviridae*, the largest and most significant virus group, and has caused significant losses in agricultural, forage, and horticultural crops. Hosts include Solanaceous, Leguminous, and *Chenopodiaceae* (i.e. spinach, chard, beets) families. Infection is transmitted in a non-persistent manner by more than 25 species of aphids and may also occur mechanically by foliar or tuber contact. Long distance transport is by winged aphids. Use certified, disease-free seed tubers to reduce primary inoculum. Insecticides may slow the spread of disease within a crop, but may actually increase insect probing and be counterproductive because only a few seconds of insect feeding is sufficient for virus transmission. Minimize contact disease spread by minimizing mechanical damage during cultivation, spraying, and harvest. Sanitize seed cutting equipment between seed lots. Remove virus-infected plants. Resistant cultivars are available.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, Potato (*Macrosiphum euphorbiae*), Green Peach (*Myzus persicae*) and others

Green peach aphids (GPA) and potato aphids (PA) are the most common colonizing aphids in potato, while buckthorn (*Aphis nasturtii*) and melon aphid (*Aphis gossypii*) and foxglove aphid (*Aulacorthum solani*) are occasional or localized pests. There are other species of aphids that do not colonize potatoes but may transmit virus as they probe potatoes in search of a host plant.

Aphids vector Potato leafroll virus (PLRV) in a persistent manner and Potato Virus Y (PVY) in a non-persistent manner. PLRV and some strains of PVY are capable of causing internal discoloration of tubers, and some strains of PVY can cause both internal and external defects on tubers of some varieties. Viruses reduce yield and quality in both seed and tablestock potatoes, and tolerance for virus is especially low in seed potato. GPA is the primary vector of PLRV and an efficient vector of PVY. Potato, buckthorn and many non-colonizing aphids are also vectors of PVY. Buckthorn aphids are the smallest of potato-infesting aphids and are more common in northern Maine, where high populations can occur quite early in the season. See green peach aphid in the insect control section of Pepper and melon aphid in the insect control section of Cucumber for more information on these pests.

Potato aphid (PA) is the largest of the colonizing aphids, 3 to 4 mm long, elongated in shape, and may be pink or green. Its antennae are as long as the body, its cornicles are long with dark tips, and on the head between the antennae the tubercles turn outward. When disturbed, PA may drop off the plant. There are both winged and wingless forms of adult females who produce live nymphs without mating, about 50 nymphs per 2 weeks. Nymphs are yellowish green or yellowish pink and become reproductive in 2 weeks. PA overwinters as eggs on plants in the rose family, feeds for several generations after hatching in spring, and colonizes a wide range of weeds, field crops, flowers, and vegetables from June through September. Vegetable crops most affected are potato, field and greenhouse tomato, lettuce, and spinach. PA feeds and builds up on young and growing plants, moving to new hosts as food quality declines. In fall they return to rose, male and female forms mate and eggs are laid. As far north as Virginia, overwintering occurs on crops such as kale and spinach, without an egg stage; in New England, winter greens in tunnels may provide a suitable habitat bridge for PA from one season to the next.

Potato aphids feed first in young growing tips, spreading downward as they multiply. (By contrast, GPA feeds in lower leaves). Leaves become distorted, with the leaf edges curling downward, and dieback occurs from the tip downward. Potato plants may be killed at high numbers.

Tomatoes show similar leaf symptoms, but blossoms are preferred, and PA colonies cause blossom drop and fruit deformities. See aphids in the insect control section of Greenhouse Tomato for more on biocontrol of PA.

Use disease-free certified seed to reduce the incidence of virus. Plant varieties that are less susceptible to viruses (See Varieties, page 250). As with other aphids, naturally occurring predators and parasitoids suppress aphid populations in the field. Use selective or systemic insecticides for Colorado potato beetle to conserve natural enemies of aphids. Spread of PLRV can be prevented when effective foliar sprays are used at threshold. However, insecticides (both systemic and foliar) offer little or no protection against PVY. Oil sprays have been shown to provide some protection from the virus transmission of non-persistent viruses, but must be reapplied regularly.

Fields should be scouted for aphids starting at 50% plant emergence in seed-producing areas, and starting in June where only fresh market or processing crops are grown. To scout, count all aphids on 25 to 50 fully expanded compound leaves (e.g., 5 per site, 10 sites across the field). The threshold for insecticide application depends on growth stage and the target market. Thresholds in fresh market and processing potato: before tuber initiation, average 2 aphids/leaf; tuber initiation to 2 weeks before vine kill, average 4 aphids per leaf; and within two weeks of vine kill, average 10 aphids per leaf. Because of the importance of seed production in Maine, the economic threshold for all types of potatoes is lower: when aphids are found on 50% of the plants or 1 winged green peach aphid is found within the field. Because aphids tend to infest the underside of leaves, good spray coverage is needed for foliar sprays.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application, 0.4 to 0.6 oz/100 lbs seed for seed-piece application; PHI 14d, REI 12h, Bee: H, Group 4A. Soil application may be at planting or as a side-dress at ground-crack during hilling (cover with at least 3" of soil).

cytraniliprole (Verimark): 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For suppression of green peach aphid only.

dimethoate (Dimethoate 4EC): 0.5 to 1 pt/A; PHI 0d, REI 48h, Bee: H, Group 1B.

dinotefuran (Venom): 0.3 lb/A foliar or 1.4 to 1.65 lbs/A soil; PHI 7d foliar, REI 12h, Bee: H, Group 4A. Soil application may be applied as a narrow band before planting, in-furrow at planting, or as a sidedress at

ground-crack during hilling and immediately covered with soil. For green peach and potato aphid only.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. For buckthorn and potato aphids.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 7d, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; PHI 7d foliar, PHI 12.5d soil, REI 12h, Bee: H, Group 4A.

imidacloprid + mancozeb (TOPS-MZ-Gaucho): 0.75 lb/100 lb seed-pieces; REI 24h, Bee: H, Group 4A. Seed-piece treatment only. Do not make subsequent application of another neonicotinoid (Group 4A) insecticide following a seed-piece treatment. Aids in control of aphids. Not registered in CT or VT.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with companion labeled aphicide.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57EC): 1 to 1.5 pt/A; PHI 0d, REI 12h, Bee: H, Group 1B.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 6d, REI 48h, Bee: H, Group 1A.

oxamyl (Vydate* C-LV): 17 to 34 oz/A; PHI 7d, REI 48h, Bee: H, Group 1A. At-planting treatments of systemic aphicides followed by mid-season Vydate application, before previous treatment starts to break down, has provided best season-long control. Note: Vydate L is NOT labeled for potatoes.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

phorate (Thimet* 20G): 8.5 to 11.3 oz/1000 row ft for light or sandy soils, 13 to 17.3 oz/1000 row ft in heavy or clay soils; PHI 90d, REI 48h, Bee: H, Group 1B. May be applied at planting in sandy or clay soils; distribute granules in furrow or band on each side of the row and incorporate. May be applied post-emergence on sandy soils only; place granules on each side of hill at seed-piece level before hilling, 4 to 6 weeks after planting.

pymetrozine (Fulfill): 2.75 to 5.5 oz/A; PHI 14d, REI 12h, Bee: L, Group 9A. Selective control of aphids including potato, melon and green peach. Translaminar. Apply at threshold, before populations build up. The “sticker” in some fungicides may inhibit leaf uptake. Consult label for mixing partners.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 7d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Transform WG): 0.75 to 1.5 oz/A; PHI 7d, REI 24h, Bees: H, Group 4C. Do not apply until after petal fall.

thiamethoxam (Actara): 3 oz/A; PHI 14d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Cruiser 5FS): 0.11 to 0.16 oz/100 lb of seed; REI 12h, Bee: H, Group 4A. Systemic seed treatment. Use only approved equipment for applying liquid seed treatment products to potatoes. See rates based on row spacing on label. For early-season protection.

thiamethoxam (Platinum): 5 to 8 oz/A; REI 12h, Bee: H, Group 4A. Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer before or during planting, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

■ Colorado Potato Beetle (*Leptinotarsa decemlineata*)

Colorado potato beetles (CPB) are 1/2" long by 3/8" wide, oval with a rounded back, and each forewing is yellow with five black stripes. CPB overwinters in the adult stage, primarily in soil (up to 12" deep) in the woods and brushy borders next to host crops, though some burrow into soil in the field. In spring, the beetles search for food plants by walking from the field edges. Heavy feeding may occur on edges on non-rotated fields. If beetles do not find host plants via walking they will fly in search of food.

In the Northeast, CPB survives on solanaceous crops and weeds, including horsenettle, nightshade, eggplant, potato and tomato (primarily seedlings). Once host plants are found adults feed, mate and lay clumps of 30 to 35 bright yellow eggs on the undersides of leaves. Eggs hatch in 7 to 10 days, depending on temperature. The larva is hump-backed, rusty-red with 2 rows of black dots along each side of its body. Feeding damage and larvae are easily seen on leaves. Larvae grow through 4 stages and reach 5/8" long before they drop to the soil and pupate. Because the last stage does 85% of the feeding damage it is critical to control larvae while they are small. Adults emerge from pupae after 10 to 14 days. In southern New England, there is a second generation of eggs, larvae and adults, while in northern New England there is one generation.

Cultural controls. The single most important tactic for CPB management is to rotate potatoes, eggplant and tomato to a field that is at least 200 yards from the previous year's fields. Barriers such as roads, rivers, woodlands, and fields with other crops are helpful. This single practice delays colonization and reduces population densities.

Mechanical barriers such as trench traps, trap crops and straw mulch also delay and reduce infestation. Install plastic-lined trench traps next to overwintering sites at least 1 week

before adults emerge. Trenches should be 1' to 2' deep and 6" to 24" wide at the top. They can be U- or V-shaped with side walls sloping at angles between 65° and 90°. Beetles walking from field borders fall into the trench and cannot fly out. Perimeter trap crops may be potatoes planted earlier than the main crop to attract beetles before the main crop emerges, or planted between overwintering sites and this season's crop. Flame, vacuum or spray border crop before beetles move into the main crop. Another approach is to plant 3 to 5 rows of potatoes treated with a systemic insecticide in a perimeter around the field; this treated border will kill up to 80% of the colonizing beetles. Straw mulch around the host crop has been shown to reduce beetle numbers. Late planting may cause beetles to leave the field before potatoes emerge, resulting in lower beetle numbers.

Natural enemies that attack CPB eggs or larvae include twelve-spotted ladybeetle, spined soldier bug, a carabid beetle, *Lebia grandis* and a parasitic tachinid fly. *Beauveria bassiana* has been shown to suppress beetle populations though it does not provide immediate control.

Colorado potato beetles rapidly develop resistance to insecticides. This can happen in as short a time as 1 year and is likely whenever a single class of insecticide is used multiple times against the same population in the same and succeeding years. The population on a single farm may develop resistance in response to management practices on that farm. Resistance to pyrethroids and neonicotinoids exists in parts of New England.

Wherever possible, growers should rotate classes of insecticides and avoid using the same chemistry more than once per year, or better, once every other year. Do not use the same chemical class on successive generations in the same year. There are enough different classes to allow this, if you plan carefully. Note the resistance group number of each insecticide and avoid using chemistries from the same group. Use newer chemistries first.

Do not try to kill every beetle in the field. Potato crops can withstand 15% defoliation without affecting yields. Avoid spraying the beetle in late season, as food reserves in the foliage 2 weeks prior to senescence add little to final tuber bulking.

Scout to determine whether or not a damaging population is present. When using products that control only larvae, scout for eggs, note egg hatch and apply controls before larvae reach third instar. For materials that control all stages, you may wait and scout for adults and larvae to determine the need to apply insecticides.

To use the threshold table below, walk the field in a V-shaped pattern and select 50 potato stalks at intervals, e.g., every 10 to 20 paces, depending on field size. Count adults, large larvae (greater than half-grown) and small larvae (less than half-grown) separately. If the number of CPB is high, an insecticide should be applied; if the number is low, no insecticide is required for that week. If the number of CPB is between high and low, no insecticide should be applied, but the field should be checked in 3 to 5 days. Otherwise, the field should be checked weekly. These thresholds are for mid-season. Late in the season, potato plants can tolerate more defoliation without affecting yields.

Action Thresholds		
Life Stage	No. of CPB per 50 stalks	
	Low	High
Adults	15 or fewer	25 or more
Small Larvae	75 or fewer	200 or more
Large larvae	30 or fewer	75 or more

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 14d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant. Make first application at 50% egg hatch. If 2 applications are needed, limit to single application per CPB generation.

acetamiprid (Assail 30SG): 1.5 to 4 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A.*

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; *PHI 0d, REI 4h, Bee: L, Group un.* For use on young larvae. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A.*

***Bacillus thuringiensis* subsp. *tenebrionis* strain SA-10 (Trident^{OG}):** 3 to 6 qt/A; *PHI 0d, REI 4h, Bees: M, Group 11.* Only use 3 qt/A rate when light populations of larvae of uniform age or size are present. Use of an adjuvant may improve efficacy, but avoid mixing with silicone-based surfactants. Do not apply while pollinators are actively visiting the treatment area.

***Beauveria bassiana* (Mycotrol ESO):** 0.5 to 1 qt/A; *PHI 0d, REI 4h, Bee: L, Group 22.* Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; *PHI 14d, REI 4h, Bee: L, Group 28.* Apply as a foliar spray. Do not apply more than twice to one generation or within a 30 day period.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; *PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.*

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application, 0.4 to 0.6 oz/100 lbs seed for seed-piece application; *PHI 14d, REI 12h, Bee: H, Group 4A.* Soil application may be at planting or as a side-dress at ground-crack during hilling (cover with at least 3" of soil).

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A for soil applications, 0.46 to 0.75 oz/100lb of seed pieces; *PHI 0d, REI 4h, Bee: H, Group 28.* For soil applications at planting and potato seed piece treatment.

cyromazine (Trigard): 2.66 to 5.32 oz/A; *PHI 7d, REI 12h, Bee: M, Group, 17.* Insect growth regulator most effective on small larvae. Does not control adult beetles.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 0.3 lb/A foliar or 1.4 to 1.65 lbs/A soil; PHI 7d foliar, REI 12h, Bee: H, Group 4A. Soil application may be applied as a narrow band before planting, in-furrow at planting, or as a sidedress at ground-crack during hilling and immediately covered with soil.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

flupyradifurone (Sivanto): 10.5 to 14 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid + mancozeb (TOPS-MZ-Gaucho): 0.75 lb/100 lb seed-pieces; REI 24h, Bee: H, Group 4A. Seed-piece treatment only. Do not make subsequent application of another neonicotinoid (Group 4A) insecticide following a seed-piece treatment. Aids in control of aphids. Not registered in CT or VT.

indoxacarb (Avaunt): 3.5 to 6 oz/A; PHI 7d, REI 12h, Bee: H, Group 22. Efficacy may be improved by the addition of piperonyl butoxide (PBO).

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

novaluron (Rimon 0.83EC): 6 to 12 oz/A; PHI 14d, REI 12h, Bee: L, Group 16B. Do not apply to successive generations. Most effective on 1st and 2nd instars. No activity against adult CPB or beneficials.

oxamyl (Vydate* C-LV): 8.5 to 34 oz/A; PHI 7d, REI 48h, Bee: H, Group 1A. NOTE: Vydate L is NOT labeled for potatoes.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 14d, REI 12h, Bee: H, Group 3A.

phorate (Thimet* 20G): 13 to 17.3 oz/1000 row ft for heavy or clay soils in early season at-planting applications; 8.5 to 11.3 oz/1000 row ft for light or sandy soils in early season post-emergence applications; PHI 90d, REI 48h, Bee: H, Group 1B. Apply at planting in heavy soil; distribute granules in furrow or band on each side of the row and incorporate. Apply post-emergence on sandy soil; place granules on each side of hill at seed-piece level before hilling, 4 to 6 weeks after planting.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 4.5 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 10 oz/A; PHI 7d, REI 4h, Bee: M, Group 5. Controls adult and larvae.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 14d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Cruiser 5FS): 0.11 to 0.16 fl. oz/100 lbs of seed; REI 12h, Bee: H, Group 4A. See rates based on row spacing on label. Systemic seed treatment. Use only approved equipment for applying liquid seed treatment products to potatoes. For early-season protection.

thiamethoxam (Platinum): 5 to 8 oz/A; REI 12h, Bee: H, Group 4A. Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer before or during planting, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed after dark. Larvae may feed on leaves, cut stems or even occasionally feed on tubers. For best results, make application between midnight and dawn while cutworms are feeding aboveground. Synthetic pyrethroids (Group 3A) may work best during cool spring weather. See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OG}): 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures.

Bacillus thuringiensis kurstaki (Dipel DF^{OG}): 0.5 to 1 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

carbaryl (10% Sevin Granules): 20 lb/A; PHI 7d, REI 12h, Bee: H, Group 1A. Apply evenly over soil surface.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 5 to 8 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 pt/A; PHI 6d, REI 48h, Bee: H, Group 1A. Variegated cutworm only.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 14d, REI 12h, Bee: H, Group 3A.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 7d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ European Corn Borer (*Ostrinia nubilalis*)

Larvae infest potato stems but rarely cause yield reductions; however, larval infestations can exacerbate drought stress. Higher levels of stem infestations have been associated with a higher incidence of blackleg. For more information on ECB, see the Sweet Corn section.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A. For use as an ovicide only.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 14d, REI 4h, Bee: L, Group 28. Apply as a foliar spray.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Verimark): 10 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 3.5 to 6 oz/A; PHI 7d, REI 12h, Bee: H, Group 22.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

novaluron (Rimon 0.83EC): 6 to 12 oz/A; PHI 14d, REI 12h, Bee: L, Group 16B.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 14d, REI 12h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 6 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 10 oz/A; PHI 7d, REI 4h, Bee: M, Group 5.

zeta-cypermethrin (Mustang*): 1.9 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Flea Beetles, Potato (*Epitrix cucumeris*) and Eggplant (*E. fuscula*)

Shiny black beetles less than 1/8" long. Adults spend the winter under plant residue along tree lines or in the field. In the early spring, they feed on solanaceous weeds until they

move to potato or other solanaceous crops. Numerous tiny feeding shot holes can injure leaves and stunt young plants. Management practices include clean cultivation, crop rotation, delayed plantings, removing or avoiding spring weed hosts, use of row covers, and applying spot treatments targeting young potato plants along the field edges. Full-size plants rarely require treatment for flea beetles. Most insecticides registered to control CPB, including spinosad, will control FB. Sweep young plants 25 times and spot treat potatoes along field edges if 50 beetles are found in the sweep net.

acetamiprid (Assail 30SG): 1.5 to 2.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 3.2 to 9.6 oz/A at cultivation or lay-by, 2.1 to 6.4 oz/A foliar; PHI 21d, REI 12h, Bee: H, Group 3A. Sweet potato and black flea beetles only. Apply as foliar spray to control adults only.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 7d, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application, 0.4 to 0.6 oz/100 lbs seed for seed-piece application; PHI 14d, REI 12h, Bee: H, Group 4A. Soil application may be at planting or as a side-dress at ground-crack during hilling (cover with at least 3" of soil).

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Suppression only.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 0.3 lb/A foliar or 1.4 to 1.65 lbs/A soil; PHI 7d foliar, REI 12h, Bee: H, Group 4A. Soil application may be applied as a narrow band before planting, in-furrow at planting, or as a sidedress at ground-crack during hilling and immediately covered with soil.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A. Apply when temperature is less than 80°F and when foliage is free from dew or other moisture.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; PHI 7d foliar, PHI 125d soil, REI 12h, Bee: H, Group 4A.

imidacloprid + mancozeb (TOPS-MZ-Gaucha): 0.75 lb/100 lb seed-pieces; REI 24h, Bee: H, Group 4A. Seed-piece treatment only. Do not make subsequent application of another neonicotinoid (Group 4A) insecticide following a seed-piece treatment. Aids in control of aphids. Not registered in CT or VT.

kaolin (Surround WP^{0G}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; *PHI 0d, REI 4h, Bee: L.* Suppression/repellence only. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior^{*} II): 1.28 to 1.92 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.*

methomyl (Lannate^{*} LV): 1.5 pt/A; *PHI 6d, REI 48h, Bee: H, Group 1A.*

oxamyl (Vydate^{*} C-LV): 17 to 34 oz/A; *PHI 7d, REI 48h, Bee: H, Group 1A.* NOTE: Vydate L is NOT labeled for potatoes.

permethrin (Pounce^{*} 25WP): 6.4 to 12.8 oz/A; *PHI 14d, REI 12h, Bee: H, Group 3A.*

phorate (Thimet^{*} 20G): 8.5 to 11.3 oz/1000 row ft for light or sandy soils, 13 to 17.3 oz/1000 row ft in heavy or clay soils; *PHI 90d, REI 48h, Bee: H, Group 1B.* May only be applied at planting in sandy or clay soils; distribute granules in furrow or band on each side of the row and incorporate. For control of larvae and reduction of adults.

pyrethrin (PyGanic EC5.0^{0G}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

thiamethoxam (Actara): 1.5 to 3 oz/A; *PHI 14d, REI 12h, Bee: H, Group 4.*

thiamethoxam (Cruiser 5FS): 0.11 to 0.16 fl. oz/100 lbs of seed; *REI 12h, Bee: H, Group 4A.* See rates based on row spacing on label. Systemic seed treatment. Use only approved equipment for applying liquid seed treatment products to potatoes. For early-season protection.

thiamethoxam (Platinum): 5 to 8 oz/A; *REI 12h, Bee: H, Group 4.* Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang^{*}): 1.9 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Potato Leafhopper (*Empoasca fabae*)

Potato leafhoppers overwinter in Louisiana and vicinity and move north on storm fronts into the central states and then into New England on winds from the west. Low levels of leafhopper feeding can severely damage plants and cause symptoms known as hopper burn. Leaves yellow, turn brown and die. Adults are light green, 1/8" long, and wedge-shaped, while nymphs are bright green, flatter and fatter than adults, and move sideways in a crab-like fashion. Sample with sweep net, or shake plants to see if adults fly up, and treat if more than 1 adult per sweep is found. Nymphs can be monitored by visually inspecting lower leaf surfaces on lower leaves. Treat if more than 15 nymphs are found per 50 leaves.

acetamiprid (Assail 30SG): 1.5 to 4 oz/A; *PHI 7d, REI 12h, Bee: M, Group 4A.*

alpha-cypermethrin (Fastac^{*} EC): 1.8 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{0G}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; *PHI 0d, REI 4h, Bee: L,*

Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake. For suppression of nymphs only.

azadirachtin & pyrethrins (Azera^{0G}): 16 to 56 oz/A foliar, drench, and greenhouse applications; *PHI 0d, REI 12h, Bee: M, Groups un & 3A.*

beta-cyfluthrin (Baythroid^{*} XL): 0.8 to 1.6 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; *PHI 7d, REI 12h, Bee: H, Group 1A.*

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application, 0.4 to 0.6 oz/100 lbs seed for seed-piece application; *PHI 14d, REI 12h, Bee: H, Group 4A.* Soil application may be at planting or as a side-dress at ground-crack during hilling (cover with at least 3" of soil).

chlorantraniliprole & lambda-cyhalothrin (Besiege^{*}): 5 to 8 oz/A; *PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.*

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{0G}): 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

deltamethrin (Delta Gold^{*}): 1.5 to 2.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.*

dimethoate (Dimethoate 4EC): 0.5 to 1 pt/A; *PHI 0d, REI 48h, Bee: H, Group 1B.*

dinotefuran (Venom): 0.3 lb/A foliar or 1.4 to 1.65 lbs/A soil; *PHI 7d foliar, REI 12h, Bee: H, Group 4A.* Soil application may be applied as a narrow band before planting, in-furrow at planting, or as a sidedress at ground-crack during hilling and immediately covered with soil.

esfenvalerate (Asana^{*} XL): 2.9 to 9.6 oz/A; *PHI 7d, REI 12h, Bee: H, Group 3A.*

fenpyroximate (Portal XLO): 2 pt/A; *PHI 7d, REI 12h, Bee: L, Group 21A.*

flupyradifurone (Sivanto): 7 to 10.5 oz/A; *PHI 7d, REI 4h, Bee: L, Group 4D.*

gamma-cyhalothrin (Declare^{*}): 0.77 to 1.28 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.*

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; *PHI 7d foliar, PHI 125d soil, REI 12h, Bee: H, Group 4A.*

imidacloprid + mancozeb (TOPS-MZ-Gaucho): 0.75 lb/100 lb seed-pieces; *REI 24h, Bee: H, Group 4A.* Seed-piece treatment only. Do not make subsequent application of another neonicotinoid (Group 4A) insecticide following a seed-piece treatment. Aids in control of aphids. Not registered in CT or VT.

insecticidal soap (M-Pede^{0G}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with companion labeled insecticide.

kaolin (Surround WP^{0G}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; *PHI 0d, REI 4h, Bee: L.* Suppression/repellence only. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior^{*} II): 0.96 to 1.6 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.*

malathion (Malathion 57EC): 1 to 1.5 pt/A; PHI 0d, REI 12h, Bee: H, Group 1B.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 6d, REI 48h, Bee: H, Group 1A.

oxamyl (Vydate* C-LV): 17 to 34 oz/A; PHI 7d, REI 48h, Bee: H, Group 1A. NOTE: Vydate L is NOT labeled for potatoes.

paraffinic oil (Organic JMS Stylet-Oil^{OG}): 0.75 to 1.5 gal/100 gal water; PHI 0d, REI 4h, Bee: L.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 14d, REI 12h, Bee: H, Group 3A.

phorate (Thimet* 20G): 8.5 to 11.3 oz/1000 row ft for light or sandy soils, 13 to 17.3 oz/1000 row ft in heavy or clay soils; PHI 90d, REI 48h, Bee: H, Group 1B. May be applied at planting in sandy or clay soils; distribute granules in furrow or band on each side of the row and incorporate. May be applied post-emergence on sandy soils only; place granules on each side of hill at seed-piece level before hilling, 4 to 6 weeks after planting.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

sulfoxaflor (Transform WG): 1.5 to 2.25 oz/A; PHI 7d, REI 24h, Bees: H, Group 4C. Do not apply until after petal fall.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 14d, REI 12h, Bee: H, Group 4.

thiamethoxam (Cruiser 5FS): 0.11 to 0.16 fl. oz/100 lbs of seed; REI 12h, Bee: H, Group 4A. See rates based on row spacing on label. Systemic seed treatment. Use only approved equipment for applying liquid seed treatment products to potatoes. For early-season protection.

thiamethoxam (Platinum): 5 to 8 oz/A; PHI 30d, REI 12h, Bee: H, Group 4. Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Wireworms, including corn wireworm (*Melanotus communis*)

Corn wireworm is reported to be the most common wireworm species in the Northeast, but others may also be present including the tobacco wireworm, (*Conoderus verspertinus*). Corn wireworm causes damage to vegetable crops including cabbage, corn, lettuce, pepper, potato and sweet potato as well as field crops including field corn, sorghum, soybean, tobacco, and wheat. Wireworms are attracted to germinating seeds and can be a seed pest in large-seeded crops such as beans, peas and corn.

Wireworms are the underground larval stage of click beetles, which are elongated, brown beetles that snap their bodies to

make a clicking sound. Adults emerge from the soil in May and June and tend to hide during the day and fly mostly at night. Egg-laying females prefer grassy or weedy fields. Eggs are deposited in the soil, often in batches. Larvae are slender, yellow-brown, hard-shelled, and shiny, with 3 pairs of legs. Wireworms spend multiple years in the soil, and completing their development from egg to adult may take 2 to 5 years depending on conditions. They feed on other insects, roots, seeds, tubers, and other plant tissue. Wireworms prefer wet soils and moderate temperatures (at least 70° F); they migrate up to reach warmer soils, but down to avoid excessive cold, heat, or drought. In agricultural fields, where other plants are eliminated, the crop itself is the primary available food source. Wireworms may injure potatoes by feeding on the seed piece resulting in weak stands, but the majority of their damage is caused by tunneling into tubers which reduces yield quality. Wireworm tunnels also provide entry to tuber pathogens, increasing tuber rots.

Tuber damage may be worse under drought conditions, where the crop provides the only source of moisture in a dry field. Wireworms are more pronounced in soils that are wet, heavy or high in organic matter. They may be worse in low areas of the field; however, they will move away from saturated soils that lack oxygen. Wireworm problems occur most often in fields that were recently in hay, pasture or sod (within the past 3 years), had grassy weeds in previous years, or were in sorghum-sudangrass or grass cover crops, or cereal grains. Forest soils may also harbor wireworms, thus recently cleared land can be infested. The most important method of wireworm control is to avoid planting potatoes or other susceptible crops in these fields.

Baits using corn or wheat or rolled oats placed 6" to 8" deep can be used to determine if wireworms are present, but these sampling methods are labor intensive, and potatoes are often planted in cold soils before such samples could be completed. A review of many insecticide trials over 2 decades indicated that organophosphate insecticides applied as a preplant broadcast or in-furrow gave better control than carbamates, and that fipronil and bifenthrin were as effective as the organophosphates, but with less environmental impact and potential human safety concerns.

bifenthrin (Brigade* 2EC): 9.6 to 19.2 oz/A at planting, for corn and tobacco wireworm only. 3.2 to 9.6 oz/A at cultivation or lay-by, 2.1 to 6.4 oz/A foliar, for southern potato wireworm only; PHI 21d, REI 12h, Bee: H, Group 3A. May be applied as soil-incorporated broadcast, bed, or t-band spray into planting furrow or soil-directed and incorporated spray at cultivation or lay-by for wireworms. May be applied as foliar spray for click beetle (adult wireworm).

ethoprop (Mocap* 15G): 1.4 lb/1000 row feet banded, 27 to 40 lb/A broadcast; REI 48h, Bee: H, Group 1B. Apply before potato emergence only. Direct contact with seed pieces may contribute to delayed emergence. Extremely toxic to birds; do not leave granules on soil surface.

fipronil* (Regent 4SC): 3.2 oz/A; PHI 90d, REI 0d, Bee: H, Group 2. Make one in-furrow treatment at planting. Must be thoroughly incorporated and covered with soil immediately after application. DO NOT use at T-band over the top of closed furrow.

imidacloprid + mancozeb (TOPS-MZ-Gaucha): 0.75 lb/100 lb seed-pieces; *REI 24h, Bee: H, Group 4A.* Seed-piece treatment only. Do not make subsequent application of another neonicotinoid (Group 4A) insecticide following a seed-piece treatment. Aids in control of aphids. Not registered in CT or VT. Suppression only.

***Isaria fumosorosea* Apopka Strain 97 (PFR-97 20% WDG^{OC}):** 1 to 2 lb/A soil drench; *PHI 0d, REI 4h, Bee: M, Group M.*

phorate (Thimet* 20G): 8.5 to 11.3 oz/1000 row ft for light or sandy soils, 13 to 17.3 oz/1000 row ft in heavy or clay soils; *PHI 90d, REI 48h, Bee: H, Group 1B.* May be applied at planting in sandy or clay soils; distribute granules in furrow or band on each side of the row and incorporate. May be applied post-emergence for suppression only on sandy soils only; place granules on each side of hill at seed-piece level before hilling, 4 to 6 weeks after planting.

thiamethoxam (Cruiser 5FS): 0.11 to 0.16 fl. oz/100 lbs of seed; *REI 12h, Bee: H, Group 4A.* See rates based on row spacing on label. Systemic seed treatment. Use only approved equipment for applying liquid seed treatment products to potatoes. For protection of seedpieces from wireworm.

thiamethoxam (Platinum): 5 to 8 oz/A; *REI 12h, Bee: H, Group 4.* Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer before or at planting, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray. For seedpiece protection only.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

A common strategy of potato growers is to combine one of the “grass” herbicides listed (EPTC, metolachlor or pendimethalin) with one of the broadleaf herbicides listed below (linuron or metribuzin). In more northern areas of New England, grasses are much less of a problem due to cooler soil temperatures, and there are many cases where only a broadleaf herbicide is necessary. If only a broadleaf herbicide is used, sethoxydim (Poast), described below, could be used during the growing season to provide emergency or spot treatment of any emerged annual or perennial grasses that were not anticipated.

Yellow Nutsedge: The herbicides that will provide the best control of yellow nutsedge, include a soil-incorporated treatment of EPTC (Eptam), a preemergence application of metolachlor (Dual) or a postemergence application of Metribuzin. The best strategy is to map the problem spots in a field and make an application of either Eptam or Dual before the nutsedge emerges. A postemergence application of Metribuzin can be used to clean any areas that escape the Eptam or Dual treatment. The best time to apply a postemergence treatment of Metribuzin is when the yellow

nutsedge is 4" to 6" tall. Remember that nutsedge is not a grass and will not be controlled by grass herbicides like Poast and Select Max.

Quackgrass: The best strategy for quackgrass control is an application of glyphosate (Roundup) to actively growing quackgrass the fall prior to planting. An application of Roundup in the spring at least 3 days prior to soil preparation will suppress quackgrass but will not kill it. EPTC (Eptam) and sethoxydim (Poast) can also be used to suppress quackgrass during the growing season. Both of these herbicides will provide greater activity if the quackgrass rhizomes (underground storage roots) are cut thoroughly with a disc prior to planting the potatoes. Also, Poast will provide better suppression of quackgrass if the lower rate is used and repeated when the quackgrass regrows (about 2 weeks after the first application). Be sure to observe the preharvest interval for both Eptam and Poast.

■ Stale Seedbed and Seedbed Preparation

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

carfentrazone (Aim EC): *REI 12h, Group 14.* Apply up to 2 oz/A per application, and do not exceed a total of 11.6 oz/ per season.

glyphosate (Roundup Power Max): *REI 12h, Group 9.* Can be applied before field preparation to control emerged perennial weeds, after stale seedbed preparation, before planting or after planting but before potatoes emerge. Any crop contact will cause crop death.

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Use 1-2 pts/A. Preplant or preemergence.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

dimethenamid (Outlook): *PHI 40d, REI 12h, Group 15.* Apply preemergence (after planting or after drag-off) as a single application. Rates are 12 to 18 oz/A on coarse-textured soils and 14 to 21 oz/A on medium- or fine-textured soils, but are also influenced by soil organic matter content. See label for rate selection. In cold and wet growing conditions, Outlook application may result in delayed emergence or early season stunting.

EPTC (Eptam 7E): *PHI 30d, REI 12h, Group 8.* Apply to dry soil surface and incorporate immediately to a depth of 2 to 3". ‘Superior’ potatoes are sensitive to Eptam and, under stress conditions, early season stunting may occur. Do not exceed 14 pt/A per season.

1. Preplant: Apply and incorporate 3.5 to 9 pt/A just before planting; use at least 4.5 pt/A for quackgrass control and a minimum of 5 pt/A to control nightshade. For incorporated applications to beds, apply as a band application and incorporate with ground or power driven tillers.

2. Preplant Before Bed Formation: Band application: Apply as a band where beds will be formed, equivalent to 3.5 pt/A (broadcast basis). Cover beds with 3 to 4" of soil with bedding discs, middle busters or other suitable bed making equipment. Care should be taken not to fold in the band treatment.

3. After planting but before potatoes emerge: Apply at a rate equivalent to 3.5 to 9 pt/A (broadcast basis).

4. Drag-Off (Come Up, Weeding Time) Incorporation: Drag-off must occur prior to application and incorporation. Apply and incorporate 3.5 to 7 pt/A after drag-off. Use the higher rate for nutsedge control. Use spike-tooth harrows or cultivation equipment for incorporation to cover with 3 to 4 inches of soil. Care should be taken not to fold in the band treatment.

5. Postemergence, Lay-by: Apply and incorporate 3.5 to 7 pt/A after potato plants have emerged from the soil. Use lower rate on coarse-textured soils. Incorporate immediately on a wet soil surface or on a dry soil surface incorporate within 36 hours. Care should be taken not to fold in the band treatment.

6. Irrigation: Meter 3.5 to 7 pt/A into the irrigation water after clean cultivation. May also be applied and incorporated after a clean cultivation as a directed spray to the base of emerged potato plants.

fomesafen (Reflex): *PHI 70d, REI 24h, Group 14.* Apply 1 pt/A as a broadcast preemergence application after planting but before potato emergence. Potato varieties may vary in their response to Reflex Herbicide. When using Reflex Herbicide for the first time on a particular variety, always determine crop tolerance before using. Do not apply Reflex Herbicide as a preplant incorporated application in potatoes or crop injury may occur. Do not apply to emerged potato plants or severe crop injury will occur.

linuron (Lorox DF): *REI 24h, Group 7.* Make a single application of 1.5 to 3 lbs/A after planting but prior to crop emergence. Rate is based on soil texture. See label for rate selection. If beds are to be dragged and/or hilled, apply after the final dragging or hilling operation. Do not spray over top of emerged potatoes. Plant seeds at least 2" deep. Apply before grasses are 2" tall and before broadleaf weeds are 6" tall, preferably just before or when weed seedlings emerge. If emerged weeds are present, add 1 pt surfactant for each 25 gal of spray mixture. Best results are obtained when application is made to moist soil, followed within 2 weeks by 1 inch to 2 inches of sprinkler irrigation or rainfall. May be tank mixed with s-metolachlor (Dual Magnum) to improve activity on annual grasses. See label for tank mixing info.

■ Herbicides Used Pre- and/or Postemergence to Weeds

metribuzin (Metribuzin 75): *PHI 60d, REI 12h, Group 5.* This product may be applied once preemergence and once postemergence. Do not exceed 1.3 pounds total per acre per season. Early maturing smooth-skinned white and all red skinned varieties may be injured with postemergence applications. The varieties Atlantic, Bellchip, Centennial, Chipbelle and Shepody are sensitive to Metribuzin. Avoid postemergence applications on these varieties. Preemergence applications on these varieties may cause crop injury under adverse weather conditions, on coarse soils, under high soil pH, with higher rates per acre and with mechanical incorporation. See label for other cautions. May be tank mixed with Dual Magnum, Eptam, or Matrix. See label for details.

Preemergence: Apply 0.3 to 0.6 lb/A as a broadcast spray after planting or drag-off but before crop emerges. Drag-off,

if used, must occur prior to application. Do not incorporate into the soil. Constant tank agitation is required.

Postemergence: Apply 0.3 to 0.6 lb/A as a broadcast spray over the tops of potato plants.

pendimethalin (Prowl H₂O): *REI 24h, Group 3.* Apply 1.5 to 3 pt/A (rate based on soil texture, see label) as a broadcast spray after planting or drag-off but before potatoes emerge. If rainfall does not occur within 7 days after application, shallow cultivation to a depth of 1" to 2" will improve control. May be tank mixed with Metribuzin or Lorox to improve broadleaf weed activity. May be tank mixed with Eptam 7E before planting to obtain control of yellow nutsedge or quackgrass.

Can be used early postemergence from crop emergence to the 6-inch growth stage. Do not apply postemergence if potatoes are under stress from cold/wet or hot/dry conditions or crop injury may occur.

s-metolachlor (Dual Magnum): *PHI 60d for applications at planting to drag-off application, PHI 40d for lay-by application. REI 12h, Group 15.* Apply Dual Magnum, either incorporated, preemergence, or postemergence to potatoes after hilling/lay-by. Use the lower rate on soils relatively coarse-textured or low in organic matter; use the higher rate on soils relatively fine-textured or high in organic matter. Effectiveness will be reduced if later cultural practices expose untreated soil. If cool, wet soil conditions occur after application, Dual Magnum may delay maturity and/or reduce yield of Superior and other early maturing potato varieties. Do not use on muck or peat soils. Do not apply both as a preemergence and an incorporated treatment. Do not apply more than 3.6 pt/A of Dual Magnum in a single crop season. Dual, alone or in combination with metribuzin, is especially helpful in controlling both yellow nutsedge and black nightshade. See label for permitted tank mixes and instructions.

Incorporated: Apply 1.0-2.0 pt/A to the soil and incorporate into the top 3 inches before planting, using a finishing disk, harrow, rolling cultivator, or similar implement. During planting and later cultural practices, avoid bringing untreated soil to the surface. Postplant incorporated application may be made any time after planting to drag-off, but before potato emergence. Use an implement that evenly distributes Dual Magnum in the top 2 inches of soil.

Preemergence: Apply 1.0-2.0 pt/A, either after planting as a preemergence, or after drag-off or hilling treatment, but before weeds emerge.

Postemergence After Hilling/Lay-by: Apply 1.67 pt/A postemergence to potatoes through after hilling/at lay-by to control Dual Magnum-sensitive species for remainder of the growing season. This application will not control emerged weeds. It may be applied over a previous Dual Magnum application, but do not apply more than 3.6 pt/A per season.

trifluralin (Treflan HFP): *REI 12h, Group 3.* Not for use in Maine. Apply single application after planting either before potatoes emerge, immediately following dragoff, or after potato plants have fully emerged. Apply 1 to 2 pt/A of Treflan HFP, with rate based on soil texture and crop, see label for details. Set incorporation equipment so that the

bed and furrow will be uniformly covered with a layer of treated soil. If the layer of treated soil is not uniform and the herbicide is concentrated over the bed, potato emergence may be delayed and stem brittleness can occur. When applying and incorporating Treflan HFP after potato plants have fully emerged, do not completely cover the foliage with treated soil.

rimsulfuron (Matrix): PHI 60d, 4 hr REI, Group 2. Can be used pre- and postemergence. Do not exceed 2.5 oz/A per year. Can be tank mixed with several herbicides. See label for details.

Preemergence: Apply 1 to 1.5 oz/A after hilling or drag-off, but before potatoes emerge. Activation by a single rainfall or irrigation event (1/3" to 1") is needed within 5 days of application. If rainfall or sprinkler activation cannot be managed, waiting for weeds to emerge and applying postemergence would result in better weed control. If weeds are present at application, add a nonionic surfactant at 1 to 2 pt/100 gal water. Weak on lambsquarters.

Postemergence: Apply 1 to 1.5 oz/A to young, actively growing weeds after crop emergence. Weeds less than 1" in height or diameter at application are most easily controlled. A rainfall or irrigation event (1/3" to 1") no sooner than 4 hours, but not more than 5 days after application, will activate Matrix in the soil and help provide control of subsequent flushes of annual weeds.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): PHI 7d, REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 11.6 oz/ per season.

clethodim (Select Max): PHI 30d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 30d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 5 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PUMPKIN, SQUASH, AND GOURDS

In the U.S., the cultivated members of the *Cucurbita* genus fall into three species: *Cucurbita pepo* (pumpkins, summer squashes, and some winter squashes), *C. maxima* (buttercup and hubbard squashes, and giant pumpkins), and *C. moschata* (butternut squashes). With the exception of *C. maxima*, whose center of origin is in South America, it is assumed that the other cultivated species were domesticated in Mesoamerica. The catch-all term "gourd" includes some members of the genus *Cucurbita* as well as some members of the genus *Lagenaria*.

Squash, pumpkins, and some gourds can be marketed for a variety of purposes: as a vegetable; as an ingredient in pies, cakes, and pastries; and as a base for cold and warm soups. Many types, edible and inedible, are marketed for their ornamental value.

Types and Varieties

There are several types of summer squashes which vary in size and shape, including: zucchini, yellow and yellow crookneck, patty pan, couasa, as well as spherical types such as 'Eight Ball.' They are harvested multiple times throughout the season (every 1-3 days), often from 2 or 3 sequential plantings. Winter squash come in diverse shapes and sizes, from very large to very small, and are harvested once at the end of the season. Pumpkins also range from small to very large. They come in white, orange, and deep red. Note that the so-called "Giant Pumpkins" are actually *C. maxima*, unlike standard pumpkins, which are *C. pepo*. Of the cucurbits, gourds are most known for their colors and shapes. Many bear names that reflect their appearance: crook-necked, winged, crown-of-thorns.

Pumpkin, Squash, and Gourd Varieties	
Miniature Pumpkin Baby Boo Bumpkin Little October Wee-B-Little Apprentice	Yellow Summer Squash Cougar - ZYMV, PRSV Early Prolific Straightneck Enterprise Fortune Gentry
Small Pumpkin (2-6 lbs) Baby Pam Cannon Ball - PMT Chucky Hybrid Pam Mystic Plus - PMT Neon Hijinks Prankster - PMT Rockafellow - PMT	Zucchini Cashflow - ZYMV Payroll - PMT, WMV2, ZYMV Leopard - PRSV, WMV2 Spineless Beauty Zucchini Elite Sebring (golden) - PMT Golden Glory (golden) - PMR, WMV2, ZYMV

<p>Medium Pumpkin (6-20 lbs) Challenger - PMR Diablo Gladiator - PMT Magic Lantern - PMT Merlin - PMT Mystic Plus - PMT Magician - PMR, ZYMV Sorcerer</p>	<p>Scallop and Speciality Summer Squash Patty Green Tint Peter Pan Starship Sunburst Eight Ball One Ball Zephyr (bi-colored) Bush Baby (striped)</p>
<p>Large Pumpkin (>20 lbs) Autumn King Big Rock Cronos - PMT Expert Gladiator Gold Medal Gold Medallion Howden Mustang - PMR Phatso III - PMR</p>	<p>Winter Squash - small, Cucurbita pepo Carnival (delicata/sweet dumpling) Delicata Honey Bear (acorn hybrid) - PMR Royal Ace (acorn hybrid) - PMT Taybelle PM (acorn hybrid) - PMR</p> <p>Winter Squash - buttercup/kabocha, C. maxima Ambercup Bon Bon Burgess Buttercup Sunshine Sweet Mama Red Kuri</p>
<p>Exhibit/Giant Pumpkin Atlantic Giant Prizewinner</p>	<p>Winter Squash - hubbard types, C. maxima Boston Marrow Blue Hubbard Ballet</p> <p>Winter Squash - spaghetti, C. pepo Tivoli Vegetable Spaghetti</p>
<p>Ornamental/Specialty Pumpkin Bunch O'Warts Knucklehead Goosebumps Rascal</p>	<p>Winter Squash - butternut, C. moschata Avalon Butternut Supreme Metro PMR - PMR Waltham</p> <p>Winter Squash - processing Golden Delicious (C. maxima) Maxim (butternut)</p>
<p>Ornamental Gourds Autumn Wings Birdhouse Crown of Thorns Galaxy of Stars Goblin Eggs Lunch Lady Spoon Snake</p>	<p>Resistant or tolerant to: PRSV: papaya ringspot virus, WMV2: watermelon mosaic virus-2, ZYMV: zucchini yellows mosaic virus, PMR: powdery mildew resistant, PMT: powdery mildew tolerant</p>

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8. Pumpkins and squash prefer well-drained soil, preferably sandy loams with high organic matter. Gourds can be grown in a wide range of soil types but mature earlier and color better on sandy soils or sandy loams that drain well and warm up early in the spring. Squashes and pumpkins are relatively heavy feeders.

Planting

Direct Seeding. Earlier planting may result in earlier harvest, but plastic mulch, row covers, raised beds, and transplants may be necessary to overcome cold-temperature conditions. Squash, pumpkins, and gourds should not be planted until after there is no danger of frost. While optimum soil temperature for germination is about 85°F, minimum soil temperature should be 65°F for direct seedings, warmer if using untreated seed. Germination may take 5-10 days, depending on soil temperature. Seeds are planted at 3/4"-1" in heavier soils, and 1-1/2" in lighter soils. Squash seeds are prone to rot in excessively wet conditions, so adjust depth accordingly.

Transplanting. In locations where the soil is slow to warm or there are insurmountable rodent problems, transplanting 3-week old seedlings is an option. Cucurbit roots are sensitive to cold soils. Root damage during removal from cell trays and transplanting must be kept to an absolute minimum. For this reason, growers often start cucurbit seeds in degradable pots that can be set directly into the field. When planting through plastic mulch, stems must not be abraded by the edge of the hole in the plastic. Leggy transplants have a lower survival rate than compact, younger seedlings.

Spacing. Plant population and spacing depend on plant growth habits and desired fruit sizes. Compact or bush-type squashes can be spaced 18"-24" apart within rows, and 3' to 5' between rows, depending on available space and accommodation for machinery. Compact squashes, particularly summer-harvested types, are typically planted through black plastic mulch for soil warmth, weed suppression, and soil moisture consistency. Well drained soils should also have drip tape under the mulch. Vining squashes are usually not planted through plastic mulch, although it is practicable on a small scale, will save labor, and will improve yield. These vining plants usually require 5'to 6' between rows, with plants spaced at 18"-30", depending on desired fruit size. Direct seedings should be heavy to allow for rodent damage and poor germination. Thinning can take place a few weeks after seeding.

Plant Nutrient Recommendation According to Soil Test Results for Pumpkin and Squash

PUMPKIN AND SQUASH	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs 2O ₅ per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate (Transplants)	50	110	60	0	0	160	110	0-40	0
Band-Place when Direct Seeding*	20-40	40	40	0-40	0	40	40	0-40	0
Sidedress When Vines Start to Run**	40-50	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	110-140	150	100	0-40	0	200	150	40-80	0

*Total N and K₂O in the band should not exceed 5.5 lb./1000' of row. Banded P₂O₅ may not be of benefit in warm soils.

**Sidedressing may not be necessary when using plastic mulch, or if organic matter can supply sufficient N; repeat sidedress in 2 to 3 weeks

Field Culture

Reduced Tillage. Pumpkins and winter squash can also be produced in strip-till or no-till systems. Seeds are planted into the stubble of a killed cover crop or harvested small grain. Herbicide may be necessary. Reduced-till systems provide erosion control, help retain soil moisture, improve soil structure, reduce weed and disease pressure, provide cleaner fruit at harvest and may facilitate planting and harvest operations during wet weather.

Pollination. Pumpkin and squash require bee activity for good fruit set. Fruit set in winter squash and pumpkin takes place largely over a 2-3 week period, while summer squash pollination takes place throughout the summer, depending on cropping sequence. Inadequate pollination results in poorly shaped fruit and excessive blossom drop. Your location may have good populations of wild bees, including native bumblebees and squash bees. Make observations to determine whether or not you need to supplement with hives. One hive of bees per acre is recommended. If honey bees are not available, bumble bees are a reliable alternative and are commercially available. Since bees can carry pollen for a mile or more, isolation of fields from other types of squash or pumpkin is rarely possible in the New England area.

Several factors other than bees and pollination may affect fruit set. Pumpkins and squash have separate male and female flowers. The numbers of female flowers, which produce fruit, is adversely affected by prolonged periods of high temperatures (more than 7 days above 90°F day and 70°F night), dry conditions just prior to and during bloom, excessive soil nitrogen, and excessive shading from the plant canopy. Sometimes low yields associated with lack of female flowers can be avoided or minimized by making several plantings over 2-3 weeks, planting several varieties, timely irrigation, and spacing pumpkins farther apart to help reduce shading.

Harvest and Storage

Summer squash. Summer squash should be harvested when fully expanded but still immature, while the rind is still glossy and easily scratched by a fingernail. This may require a 1-3 day picking interval. Zucchini may be harvested by cutting the stem with a knife, while straight-neck and crookneck can be twisted from the plant. Spines on the petioles can easily damage the surface of fruits, so they should be pulled out of the plant canopy carefully. Cutting with a knife can transmit virus. If virus is detected in the field, fruit should be harvested by twisting from the plant.

Summer squash can be damaged from 3 or 4 days of exposure to temperatures of 32°-40°F and 90% or higher relative humidity. This is commonly referred to as “chilling injury.” If storage is required, hold at 45°-50°F and at 90% relative humidity for up to 2 weeks. Summer squash should be marketed as soon as possible.

Winter squash and pumpkin. For winter squash, good yields of smaller varieties are 5-7 tons per acre or 2000-4000 fruit. The large types (fresh market) may yield up to 10-30 tons per acre or 1000-2000 fruit. Winter squash and pumpkin are not normally harvested until the rind or skin is completely hardened. If necessary, pumpkins can be harvested as soon as some color is present. If possible, pumpkins that have

reached full color should be stored under cover to protect them from chilling injury from temperatures below 50°F and from disease. Fruits are easily damaged by rough handling. Do not permit fruits to be exposed to 32°F, as this can promote storage problems.

Winter squash should be well matured for storage, and free from injury or decay. A 10- to 20-day curing period at 80°-85°F before storage is often recommended for squash showing any surface damage or with skin that has not hardened. Such a curing period may provide no benefit to undamaged, well-matured fruits. For the longer term, winter squash should be stored between 55°F and 60°F. Research has demonstrated that disease is minimized at 60°F and at 50%-75% relative humidity. Chilling injury occurs any time the temperatures fall below 55°F, either in the field or in storage. Damage is cumulative; injury increases as temperature decreases and/or length of chilling time increases. Such squash is likely to break down in storage.

Pumpkin can be stored in good condition for 2-3 months at 50°-55°F and 70%-75% relative humidity. Hubbard and butternut squash can be kept 6 months or more, acorn 5-8 weeks and buttercup 2-3 months or more. Squash should not be stored with ethylene producers such as ripe apples or pears since squash will turn color, become stringy and decay. It is important to keep squash dry and maintain good air circulation.

Gourds. Gourds should mature between late summer and the first fall frost. Harvest fruit when the stems become dry and the skin is hard. Discard any fruit which is bruised, cut, or showing symptoms of disease. Wash gourds in warm, soapy water to remove any soil and reduce postharvest rots.

Rinse fruit in clean water and dry with a soft cloth. Spread the gourds out on several layers of newspaper in a warm, dry place, such as an attic, for final drying. This should take 3-4 weeks.

Dried gourds may be marketed in their natural state or treated with a protective, shiny coating. Gourds may be waxed with a paste-type wax and buffed with a soft cloth; or shellac may be applied by spraying, brushing, or dipping to give them a hard, glossy finish.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Anthracnose (*Colletotrichum*), Alternaria, and Black Rot (*Stagonosporopsis* spp. formerly *Didymella bryoniae*)

Do not plant winter squash or pumpkins for at least two years in fields where these diseases have been a problem. Plow under plant debris after harvest. Reduce weeds to allow for faster drying of plant surfaces. Start with certified disease-free seed. Carefully scout transplant greenhouse for

diseased plants and remove them, improve ventilation in greenhouse, and reduce overhead irrigation. Avoid injuring fruit before or during harvest. Apply protectant fungicides according to a disease forecasting system (Melcast). Black rot, also known as gummy stem blight (GSB) is one of the most destructive diseases of winter squash and pumpkins. Cultivars with resistance to Anthracnose are available.

azoxystrobin (Quadris F): 11.0 to 15.5 fl oz/A; PHI 1d, REI 4h, Group 11. Do not alternate with other Group 11 fungicides. Resistant isolates of Black Rot (*Stagonosporopsis*) have been reported. See label for application methods and mixing instructions.

azoxystrobin plus chlorothalonil (Quadris Opti): 3.2 pt/A; PHI 1d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 12.0-14.0 fl oz/A; PHI 1d, REI 12h, Groups 11 & 3.

Bacillus mycooides Isolate J (LifeGard WG^{OC}): 4.5 oz/100 gal water; PHI 0d, REI 4h, Group P6. See label for application methods and instructions. Labeled only for GSB and anthracnose.

Bacillus subtilis strain QST 713 (Serenade ASO^{OC}): 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. See label for tank mixing precautions.

boscalid (Endura): 6.5 oz/A; PHI 0d, REI 12h, Group 7.

chlorothalonil (BravoWeather Stik): 1.5 to 3.0 pt/A; PHI 0d, REI 12h, Group M5. Bravo can cause injury to watermelon fruit; see label. Rates vary for each disease; see label. For other products, see labels.

chlorothalonil plus oxathiapiprolin (Orondis Opti): 1.7 to 2.5 pt/A; PHI 0d, REI 12h, Groups M5 & 49.

chlorothalonil plus potassium phosphite (Catamaran): 4.0 to 6.0 pt/A; PHI 0d, REI 12, Groups M5 & 33.

copper compound (Champ 2F): 1.33 pt/A; PHI 0d, REI 48h, Group M1. Label varies with manufacturer and formulation. REI for products ranges from 4 to 48 hr.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0-14.0 oz/A; PHI 1d, REI 12h, Groups 9 & 12. Labeled for only GSB and Alternaria.

cymoxanil plus chlorothalonil (Ariston): 1.9 to 3.0 pt/A; PHI 3d, REI 12h, Groups 27 & M5.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 oz/A; PHI 0d, REI 12h, Groups 3 & 7.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 7d, REI 12h, Group 3 & 9. Apply in sufficient volume to achieve thorough coverage. Do not use for the control of gummy stem blight.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Tank mix with an appropriate contact fungicide with a different mode of action.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 14d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides. Labeled for Alternaria and downy mildew only.

flutriafol (Rhyme 2.08 SC): 5.0 to 7.0 fl oz/A; PHI 0d, REI 12h, Group 3. Labeled for GSB only.

floxapyrad plus pyraclostrobin (Merivon): 4.5 to 5.5 fl oz/A; PHI 0d, REI 12h, Groups 7 & 11. Make no more than two sequential applications before alternating with a fungicide with a different mode of action.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; PHI 5d, REI 48h, Groups M3 & M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette. Not for gummy stem blight.

penthiopyrad (Fontelis): 12.6 to 16.0 fl oz/A; PHI 1d, REI 12h, Group 7. Labeled only for GSB and Alternaria. Should be used for control of GSB where group 7 fungicide resistance is suspected. Tank mix with a minimum of 1.5lb active chlorothalonil/A.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11. Do not make more than one application of Cabrio before alternating to a labeled fungicide with a different mode of action.

pyraclostrobin plus boscalid (Pristine): 12.5 to 18.5 oz/A; PHI 0d, REI 12h, Groups 11 & 7. Use caution in the addition of adjuvants or additives (see label).

Reynoutria sachalinensis extract (Regalia): 1.0 to 4.0 qt/A, foliar or ground application; PHI 0d, REI 4h, Groups P5. Apply to ensure thorough coverage.

thiophanate-methyl (Topsin M WSB): 0.5 lb/A; PHI 1d, REI 24h, Group 1. Consecutive use of Topsin M may lead to buildup of resistant strains of fungi and loss of disease control. MAY be tank mixed with chlorothalonil or mancozeb. Labeled for GSB and anthracnose. See label for application methods.

zoxamide + chlorothalonil (Zing!): 36 fl oz/A; PHI 0d, REI 12h, Groups 22 & 5. Do not combine with anything other than water. See label for restrictions.

■ Downy Mildew (*Pseudoperonospora cubensis*)

Pseudoperonospora cubensis infects only members of the cucurbit family and is an obligate parasite. Its survival depends on the presence of cucurbit hosts, either in climates which permit their growth year round or in greenhouse culture. The source of primary inoculum in cold climates is windblown sporangia from areas where plants survive the cold season. Generally, downy mildew of cucurbits does not arrive in southern New England until September. However, in some seasons it can move up the eastern seaboard early and arrive in July. The progress of downy mildew is tracked by the North American Plant Disease Forecast Center and warnings issued based on disease progression and weather (<http://cdm.ipmpipe.org/>). Physiological specialization occurs in *P. cubensis* and at least 5 pathotypes have been described. Cucumber and melon are susceptible to all pathotypes, while squash and melon cultivars vary in their reactions. Spread of downy mildew within a field can be by air currents, rain splash, workers, and tools. The main means of control are fungicide applications, the use of resistant cultivars, and cultural practices. Maximum control can be achieved only with a combination of these measures. Maximize the distance from potential inoculum sources. Use plant spacings that reduce the density of the plant canopy. Avoid overhead

irrigation. Both these practices are aimed at minimizing the length of leaf wetness periods. Squash and pumpkin cultivars are resistant to some pathotypes but are very susceptible to compatible pathotypes.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 & 40.

azoxystrobin (Quadris F): 11.0 to 15.5 fl oz/A; PHI 1d, REI 4h, Group 11. Do not alternate with other Group 11 fungicides. See label for application methods and mixing instructions.

Bacillus mycoides Isolate J (LifeGard^{OG}): 4.5 oz/100 gal water; PHI 0d, REI 4h, Group P6.

Bacillus subtilis strain QST 713 (Serenade ASO^{OG}): 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. See label for tank mixing precautions.

chlorothalonil (Bravo Weather Stik): 1.5 to 2.0 pt/A; PHI 0d, REI 12h, Group M5.

chlorothalonil plus oxathiapiprolin (Orondis Opti): 1.7 to 2.5 pt/A; PHI 0d, REI 12h, Groups M5 & U15. See label for application methods and restrictions.

copper hydroxide (Kocide 3000): 0.5 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Discontinue use if crop injury occurs. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

copper oxychloride plus copper hydroxide (Badge SC): 0.5 to 2.0 lb/A; PHI 0d, REI 48h, Group M1.

cyazofamid (Ranman): 2.1 to 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Tank mix with an organosilicone surfactant or non-ionic surfactant. Alternate sprays of Ranman with a fungicide with a different mode of action.

cymoxanil (Curzate 60 DF): 3.2 to 5.0 oz/A; PHI 3d, REI 12h, Group 27. Use only in combination of a labeled rate of a protectant fungicide (copper, chlorothalonil).

cymoxanil plus chlorothalonil (Ariston): 1.9 to 3.0 pt/A; PHI 3d, REI 12h, Groups 27 & M5.

dimethomorph (Forum): 6.0 oz/A; PHI 0d, REI 12h, Group 40. Apply only in combination with a labeled rate of another non-group 40 fungicide. Do not make more than two sequential applications of Forum before alternating to a fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Tank mix with an appropriate contact fungicide.

fenamidone (Reason 500 SC): 5.5 fl oz/A; PHI 14d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

fosetyl Al (Aliette 80 WDG): 2.0 to 5.0 lb/A; PHI 12d, REI 12h, Group 33. Do not tank mix with copper. See label for other restrictions.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; PHI 5d, REI 24h, Group M3. Do not tank mix with copper. See label for application methods and restrictions.

mancozeb plus copper hydroxide (ManKocide): 2.0-3.0 lb/A; PHI 5d, REI 48h, Groups M3 & M1. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

oxathiapiprolin (Orondis Ultra A): 2.0 to 4.8 fl oz/A; PHI 0d, REI 4, Group 49.

oxathiapiprolin plus chlorothalonil (Orondis Opti): 1.75 to 2.5 fl oz/A; PHI 0d, REI 4, Group 49 & M5.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; PHI 0d, REI 4, Group 49 & 40.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; PHI 0d, REI 4h, Group 33. Do not apply to plants that are heat or moisture stressed. Copper phytotoxicity may occur; see label.

propamocarb HCl (Previcur Flex): 1.2 pt/A; PHI 2d, REI 12h, Group 28. Alternate with a contact fungicide (copper, chlorothalonil, sulfur).

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; PHI 0d, REI 12h, Group 11. Do not make more than one application before alternating with a non-Group 11 fungicide.

pyraclostrobin plus boscalid (Pristine): 12.5 to 18.5 oz/A; PHI 0d, REI 12h, Groups 11 & 7. Use caution in the addition of adjuvants or additives (see label).

Reynoutria sachalinensis extract (Regalia): 1.0 to 4.0 qt/A; foliar or ground application; PHI 0d, REI 4h, Groups P5. Apply to ensure thorough coverage. Apply with another fungicide for downy mildew; see label.

trifloxystrobin (Flint): 3.80 fl oz/A; PHI 0d, REI 12h, Group 11. Do not rotate with another group 11 fungicide. Labeled for disease suppression only. See label for restrictions.

zoxamide + chlorothalonil (Zing!): 36.0 fl oz/A; PHI 0d, REI 12h, Groups 22 & M5. Do not combine with anything other than water. See label for restrictions.

zoxamide plus mancozeb (Gavel75DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48h, Groups 22 & M3. Do not tank mix Gavel with another M3 fungicide if the target pest is only downy mildew. Tank-mix only if a partner is required to control other diseases, such as copper for bacterial disease.

■ Phytophthora Blight and Fruit Rot

Phytophthora capsici cannot be managed by fungicide applications alone; successful disease control is achieved only by a season-long effort to manage water and other cultural practices. The single most effective way to control this disease is to prevent its movement into clean fields by equipment, humans, or infested water. Plant susceptible crops (tomatoes, peppers, eggplant, and all cucurbit species) in fields that have no history of this disease and are well-drained (lima beans have also been reported as susceptible). Plant non-vining crops on raised beds, avoid planting in low areas where water puddles, and improve drainage by sub-soiling after heavy rain events. Promptly disk under small areas where the disease appears along with a border of healthy appearing plants. Avoid working in wet fields and compacting the soil.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 & 40.

Bacillus subtilis strain QST 713 (Serenade ASO^{OG}): 2.0 to 6.0 qt/A; PHI 0d, REI 4h, Group 44. See label for tank mixing precautions.

cyazofamid (Ranman): 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Mix with a surfactant for best results. Alternate sprays of Ranman with a fungicide with a different mode of action.

dimethomorph (Forum): 6.0 fl oz/A; *PHI 0d, REI 12h, Group 40*. Apply only in combination with a labeled rate of another non-group 40 fungicide. Do not make more than 2 sequential applications of Forum before alternating to a fungicide with a different mode of action.

famoxadone plus cymoxanil (Tanos): 8.0 to 10.0 oz/A; *PHI 3d, REI 12h, Groups 11 & 27*. For SUPPRESSION of foliar and fruit phase ONLY. Tank mix with an appropriate contact fungicide with a different mode of action (copper or chlorothalonil).

fluopicolide (Presidio): 3 to 4 fl oz/A; *PHI 2d, REI 12h, Group 43*. Must be tank mixed with another fungicide with a different mode of action.

fosetyl-Al (Aliette WDG): 2.0 to 5.0 lb/A; *PHI 0d, REI 12h, Group 33*. Do not tank mix with copper compounds. Use the high rate when *Phytophthora* blight is active.

oxathiapiprolin (Orondis Ultra A): 2.0 to 4.8 fl oz/A; *PHI 0d, REI 4, Group 49*.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; *PHI 0d, REI 4, Group 49 & 40*.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; *PHI 0d, REI 4h, Group 33*. Do not apply to plants that are heat or moisture stressed. Copper phytotoxicity may occur if applied in alternation with copper.

***Reynoutria sachalinensis* extract (Regalia):** 1.0 to 4.0 qt/A; foliar or ground application; *PHI 0d, REI 4h, Groups P5*. Apply to ensure thorough coverage. Tank mix with another fungicide labeled for downy mildew control; see label.

zoxamide plus mancozeb (Gavel75DF): 1.5 to 2.0 lb/A; *PHI 5d, REI 48h, Groups 22 & M3*. Do not tank mix Gavel with another M3 fungicide if the target pest is only *Phytophthora* blight. Tank-mix only if a partner is required to control other diseases, such as copper for bacterial disease.

■ Plectosporium Blight (*Plectosporium tabacinum*)

When *Plectosporium* blight occurs, rotate away from summer squash and pumpkins for 2 years. Choose sunny, well-drained sites for planting cucurbits. Scout for disease and apply fungicides when disease first occurs. Thorough coverage of foliage, vines, and fruit is necessary for good control. The Strobilurin (QoI) fungicides Flint (trifloxystrobin), Cabrio (pyraclostrobin), and Quadris (azoxystrobin) will control this disease but should not be rotated with each other or the pathogen will develop resistance. Apply a protectant fungicide such as chlorothalonil (Bravo) or mancozeb (Dithane) following a strobilurin.

azoxystrobin plus difenoconazole (Quadris Top): 12.0-14.0 fl oz/A; *PHI 1d, REI 12h, Groups 11 & 3*. Do not rotate with another group 11 fungicide.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 oz/A; *PHI 0d, REI 12h, Groups 3 & 7*.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; *PHI 7d, REI 12h, Group 3 & 9*. Apply in sufficient volume to achieve thorough coverage.

floxapyroxad plus pyraclostrobin (Merivon): 4 to 5.5 fl oz/A; *PHI 0d, REI 12h, Groups 7 & 11*. Make no more than

two sequential applications before alternating with fungicides that have a different mode of action.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; *PHI 5d, REI 24h, Group M3*. Do not tank mix with copper. See label for application methods and restrictions.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; *PHI 0d, REI 12h, Group 11*. Do not rotate with other Group 11 fungicides such as Quadris or Flint.

trifloxystrobin (Flint): 2.0 to 3.8 oz/A; *PHI 0d, REI 12h, Group 11*. Do not rotate with other Group 11 fungicides such as Quadris or Cabrio.

■ Post-Harvest Fruit Rot (Various Fungi)

Fruit and stem rot that develops after harvest is generally due to infection that took place in the field. Postharvest rot can be reduced by applying fungicides during the growing season on a regular basis, as for control of black rot. Control weeds to allow better air circulation. Wounds to the fruit that occur during harvest can also result in postharvest rot. For maximum storage life, refer to Harvest and Storage in the Cultural Practices section.

■ Powdery Mildew (*Podosphaera xanthii*)

Fungicides should be applied at the first sign of disease (or earlier with some products). Begin scouting for powdery mildew at fruit initiation. On cucurbits, powdery mildew fungi attack both the top and bottom of the leaf, and this makes the disease more difficult to control with non-systemic fungicides. However, powdery mildew fungi tend to become resistant to systemic fungicides such as Topsin-M (Group 1); Cabrio, Flint Extra, Quadris and Sovran (Group 11). Resistance to Group 1 and Group 11 fungicides has resulted in the removal of these classes of fungicides from recommendations, with the exception of Pristine which is a combination product. Resistance to the DMI fungicides (Rally, Procure) is also widespread; use Rally or Procure at the high labeled rate only. The most effective contact fungicides are sulfur, mineral oil, and chlorothalonil. Begin applying fungicides when powdery mildew is at a low level (threshold is 1 of 50 old leaves with symptoms on either leaf surface) or on a preventative schedule for fields not scouted; do not begin using mobile fungicides when disease is widespread. A seven-day interval is recommended.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel^{OG}):** 0.25 to 3.0 lb/A; *PHI 0d, REI 4 h, Group 44*. Labeled for disease suppression only. For improved control; mix or rotate with a chemical fungicide.

***Bacillus subtilis* strain Q713 (Serenade Max^{OG}):** 1.0 to 3.0 lb/A; *PHI 0d, REI 4h, Group 44*. Provides limited, contact control. Thorough coverage is necessary. Consider mixing with another contact fungicide.

***Bacillus mycoides* Isolate J (LifeGard^{OG}):** 4.5 oz/100 gal water; *PHI 0d, REI 4h, Group 44*. See label for application methods.

botanical extract (Regalia^{OG}): 1 to 4 qt/A; *PHI 0d, REI 4h, Group P*. Apply to assure thorough coverage.

chlorothalonil (Bravo Weather Stik): 2 to 3 pt/A; *PHI 0d, REI 12h, Group M5*. (Severe eye irritant, observe WPS provisions.)

copper compound (Champ 2F): 1.33 pt/A; *PHI 0d, REI 48h, Group M1*. Label varies with manufacturer and formulation. REI for products ranges from 4 to 48 hr. Discontinue use if crop injury occurs.

copper hydroxide (Kocide 3000): 0.5-1.25 lb/A; *PHI 0d, REI 48h, Group M1*. Discontinue use if crop injury occurs. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

cyflufenamid (Torino): 3.4 oz/A; *PHI 0d, REI 4h, Group U6*.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; *PHI 1d, REI 12h, Groups 9 & 12*.

cymoxanil plus chlorothalonil (Ariston): 3.0 pt/A; *PHI 3d, REI 12h, Groups 27 & M5*.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; *PHI 7d, REI 12h, Group 3 & 9*. Apply in sufficient volume to achieve thorough coverage.

flutriafol (Rhyme 2.08 SC): 5.0 to 7.0 fl oz/A; *PHI 5d, REI 12h, Group 3*. See label for surfactant recommendations and restrictions.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; *PHI 5d, REI 48h, Groups M3 & M1*. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

metrafenone (Vivando): 15.4 fl oz/A; *PHI 0d, REI 12h, Group U8*. Must be applied before symptoms appear. For established infections, apply in a tank mix with a curative fungicide. Make no more than 3 applications per year. Rotate to a fungicide with a different Group # after 2 applications. Do not mix with horticultural oil.

monopotassium phosphate (Nutrol): 8.0 to 12.0 lb/A; *PHI 0d, REI 4h, Group NC*. Apply 2 to 4 sprays beginning at fruit set. Use a maximum of 3 lb product/10 gal spray solution. See label for application methods and restrictions.

myclobutanil (Rally 40WS): 2.5 to 5.0 oz/A; *PHI 0d, REI 24h, Group 3*. Observe a 30-day plant back interval. See label.

neem botanical oil (Trilogy^{OG}): 0.5 to 1% solution/25 - 100 gal water; *PHI 0d, REI 4h, Group NC*. See label for application method. Thorough coverage is essential.

Paraffinic (mineral oil) (JMS Stylet-Oil^{OG}): 3.0 to 6.0 qt/100 gal water; *PHI 0d, REI 4h, Group NC*. Spray for thorough coverage of upper leaf surface.

penthiopyrad (Fontelis): 12.0 to 16.0 fl oz/A; *PHI 1d, REI 12h, Group 7*.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19*.

potassium bicarbonate (Kaligreen^{OG}): 2.5 to 5.0 lb/A; *PHI 1d, REI 4h, Group NC*.

pyraclostrobin plus boscalid (Pristine): 12.5 to 18.5 oz/A; *PHI 0d, REI 12h, Groups 11 & 7*.

quinoxifen (Quintec): 4.0 to 6.0 fl oz/A; *PHI 3d, REI 12h, Group 13*. Tank mix with a protectant fungicide. Alternate with a non-Group 13 fungicide. Not labeled for use on edible-peel cucurbits.

Reynoutria sachalinensis extract (Regalia): 1.0 to 4.0 qt/A; foliar or ground application; *PHI 0d, REI 4h, Groups P5*. Use preventatively, before any disease development. Apply to ensure thorough coverage. Recommended to mix with a mobile fungicide.

sulfur (Microthiol Disperss): 5.0 to 10.0 lb/A; *PHI 0d, REI 24h, Group M2*. Sulfur can injure plants, especially when temperatures reach 90°F. Do not apply to sulfur sensitive varieties.

triflumizole (Procure 480SC): 4.0 to 8.0 fl oz/A; *PHI 0d, REI 12h, Group 3*. Use at the highest rate to prevent resistance development.

■ Scab (*Cladosporium cucumerinum*)

Scab is a significant problem for summer and winter squash, pumpkin, melon, and watermelon. Resistant cultivars of cucumber are widely available. Where scab has been a problem, plant in sunny locations where cool air does not tend to accumulate. The pathogen survives in the soil on infected crop debris, may be seedborne, and is capable of saprophytic growth. Rotate with non-cucurbit crops for 2-3 years. Select sites with well-drained soil and good air movement for rapid drying of foliage and fruit. Avoid overhead irrigation and dense plant canopies. Fungicide sprays may not be effective during extended cool, wet weather due to the short disease cycle of this pathogen.

chlorothalonil (Bravo Weather Stik): 2.0 to 3.0 lb/A; *PHI 0d, REI 12h, Group M5*. Use caution when applying to watermelon; see label for restrictions.

chlorothalonil plus potassium phosphite (Catamaran): 6.0 pt/A; *PHI 0d, REI 12, Groups M5 & 33*.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 oz/A; *PHI 0d, REI 12h, Groups 3 & 7*.

mancozeb (Dithane F45): 1.6 to 2.4 qt/A; *PHI 5d, REI 24h, Group M3*.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; *PHI 5d, REI 48h, Groups M3 & M1*. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; *PHI 0d, REI 4h, Group 19*. Mix in sufficient water to ensure thorough coverage. See label for water volumes.

■ Angular leaf spot (*Pseudomonas lachrymans*)

Angular leaf spot is occasionally a serious disease in New England during wet seasons. Plow under crop residue after harvest. Rotate away from cucurbits for at least one year.

***Bacillus subtilis* strain QST713 (Serenade ASO^{OG}):** 2.0 to 4.0 qt/A; *PHI 0d, REI 4h, Group 44*. See label for mixing precautions.

copper hydroxide (Kocide 3000): 0.5 to 1.25 lb/A; *PHI 0d, REI 48h, Group M1*. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette. Discontinue use if crop injury occurs; see label.

mancozeb plus copper hydroxide (ManKocide): 2.0 to 3.0 lb/A; *PHI 5d, REI 48h, Groups M3 & M1*. Do not apply in a spray solution having a pH of less than 6.5 or tank mix with Aliette.

■ Bacterial Wilt (*Erwinia tracheiphila*)

Because this bacterium is transmitted systemically by cucumber beetles, copper sprays are of no value. Cucumber beetles must be controlled by appropriate insecticide programs. Scout twice weekly at seedling stage for cucumber beetles. Treat when beetle numbers reach the threshold of 1 beetle per 100 feet of row. Use crop rotation to reduce beetle numbers. Rogue infected plants. Spunbonded row covers will exclude beetles. Plant a sprayed perimeter trap crop of Blue Hubbard squash to protect more susceptible crops.

■ Cucurbit Viruses: CMV, WMV-II, PRSV-W and ZYMV

Refer to the discussion of these viruses in the section in Cucumber, Muskmelon and Watermelon.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Caution: Insecticides should not be applied when bees are active in the field. Avoid products with high or moderate bee toxicity during bloom. If application of an insecticide is necessary while the crop is blooming, select products with low bee toxicity or with short residual period; apply in the evening after the bees have left the field. See Protecting Honeybees and Native Pollinators or more suggestions on how to avoid harmful effects on pollinators.

■ Aphids, Green Peach (*Myzus persicae*) and Melon (*Aphis gossypii*)

Aphids found in cucurbits include green peach aphid and melon aphid. For more information on these aphids, see the green peach aphid in the insect control section of Pepper and the melon aphid in the insect control section of Cucumber.

Scout weekly for aphids by inspecting the underside of 5 fully grown leaves at each of 10 sites per field. Note what proportion of leaves have 5 or more aphids and treat if 20% of leaves have 5 or more aphids per leaf and the population is increasing. Pumpkin, gourd and squash varieties differ in attractiveness to aphids. Spot treatment of susceptible varieties may be appropriate. Use selective products to conserve beneficials that suppress aphids. During bloom, avoid products that are toxic to bees, or treat in the evening after bees stop foraging.

acetamiprid (Assail 30 SG): 2.5 to 4 oz/A; PHI 0d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 3 oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

azadirachtin (Azatin ^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A melon aphid, 10 to 13.5 oz/A green peach aphid; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting or drip chemigation during the first half of the crop growing cycle.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

dinotefuran (Safari 20SG): 3.5 to 7 oz/100 gal; 7 to 14 oz/A; 0.16 to 0.32 oz/sq ft.; REI 12h, Bee: H, Group 4A. Squash transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. Do not apply to vegetables grown for seed.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; 0.44 fl oz/10,000 plants on seedling transplants in greenhouse; PHI 21d, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection. Not for foliar applications.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May require repeated applications. Apply with a labeled companion insecticide on green peach aphids; on other aphids, use of a companion insecticide is recommended for enhanced and residual control.

lambda-cyhalothrin (Warrior* II): 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57EC): 1.5 pt/A; PHI 1d, REI 12h for winter squash and pumpkin, 24h for summer squash, Bee: H, Group 1B.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d for 1.5 pt/A, PHI 3d for over 1.5 pt/A, REI 48h, Bee: H, Group 1A. For summer squash and other “soft” squash that is harvested and consumed when immature only. For melon aphid.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A.

petroleum oil (Suffoil X): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For pumpkin and squash only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee:M, Group 3A.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9A. Selective control of aphids including melon and green peach aphid. Translaminar. Apply before populations build up.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting operations.

tolfenpyrad (Torac): 17 to 21 fl oz/A; PHI 1d, REI 12 h, Bee: H, Group 21A.

■ Cucumber Beetle, Striped (*Acalymma vittatum*) and Spotted (*Diabrotica undecimpunctata*)

See the insect section of Cucumber for more information on cucumber beetle life cycle and cultural management. In pumpkin and squash, manage striped cucumber beetle to prevent losses from direct feeding damage as well as from bacterial wilt vectored by beetle feeding. The most susceptible period is from crop emergence to the 5 true-leaf stage. Scout at least 25 plants to monitor the number of beetles and damage. An action threshold of 1 to 2 beetles per plant is recommended; use the higher threshold for crops with vigorous early growth and lower susceptibility to wilt, such as butternut and pumpkin, and the lower threshold for summer squash. At later growth stages, the crop should be treated if there is significant damage to fruit. Fruit feeding by adult beetles may occur late in the season especially on pumpkin. Where possible, avoid insecticide applications during flowering to protect bees; if sprays are needed, treat after dark when bees are no longer foraging and use products that have low impact on bees. If multiple treatments are needed, rotate to a product with a different mode of action.

Perimeter trap cropping has been shown to reduce or eliminate main crop sprays while providing effective control of beetles. Plant 1 or 2 rows of Blue Hubbard, buttercup squash or another *Cucurbita maxima* variety in an unbroken perimeter around the field. Always use 2 rows near woods or last year’s fields, and space plants no wider than the between-row spacing that is used in the main crop between-row spacing. These perimeter crops will concentrate incoming beetles in the border because they are generally more attractive to beetles than winter squash, summer squash and pumpkin, which are *Cucurbita moschata* or

Cucurbita pepo types. Note that some specialty pumpkin varieties are *Cucurbita maxima* types and very attractive to beetles. Do not use a crop that is highly susceptible to bacterial wilt in the border. Beetles should be killed in the border, either by applying foliar insecticide when beetles first arrive or using a systemic insecticide at planting. Scout both borders and main crop to assess beetle numbers. Repeat perimeter-sprays if needed to prevent influx into the main crop, and spray the main field if thresholds are exceeded. Attractive crop types that are planted in rows within the main field also work as trap crops that draw beetles as they move around within the field. These trap crops can be selectively sprayed.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 0d, REI 12h, Bee: M, Group 4.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee:M, Groups un & 3A.

beta-cyfluthrin (Baythroid* XL): 2.4 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A. Do not apply when foliage is wet.

cryolite (Prokil Cryolite): 8 to 16 lb/A; PHI 7d summer squash, 14d pumpkins and winter squash, REI 12h, Bee: L, Group un.

cyclanilprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 1 to 4 oz/A foliar; PHI 1d, REI 12 hr, Bee: H, Group 4A. Do not apply to vegetables grown for seed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A. Adults only.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee:H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A; PHI 21d, REI 12h, Bee: H, Group 4A. Soil applications only.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 1/4 to 1/2 lb/gal for backpack sprayer; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 1/4 of its expected harvest size. Follow label instructions for mixing. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A. Adults only.

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 1d for 1.5 pt/A, PHI 3d for over 1.5 pt/A, REI 48h, Bee: H, Group 1A.* For summer squash and other “soft” squash that is harvested and consumed when immature only. For melon aphid.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.* Adults only.

petroleum oil (Suffoil X): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed. For beetle larvae only. For pumpkin and squash only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. Suppression only.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Adults only.

■ Cutworms

Caterpillars hide under the soil surface adjacent to the plant stem during the day and feed after dark. Larvae may occasionally cut stems of seedlings. Spot spray heavily damaged sections of the field. For best results, make application between midnight and dawn while cutworms are feeding aboveground. For more information see black and variegated cutworms in insect control sections of Pepper and Tomato (Outdoor).

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening before larvae are actively feeding and direct sprays to base of stem.

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.*

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.*

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; *PHI 3d, REI 12h, Bee: H, Group 3A.* Seedling spray only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.*

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; *PHI 3d, REI 4h, Bee: M, Group 5.* Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

■ Seedcorn Maggot (*Delia platura*)

For more information, see seedcorn maggot in the insect control section of Bean.

cyantraniliprole (Verimark): 10 to 13.5 oz/A soil; *PHI 1d, REI 4h, Bee: H, Group 28.* Apply as in-furrow spray or transplant tray drench no earlier than 72 hours prior to planting in field, or as transplant water treatment, hill drench, or surface band.

■ Slugs

For more information see slugs in the insect control section of Cabbage.

iron phosphate (Sluggo: Snail and Slug Bait^{OG}): 20 to 44 lb/A; *PHI 0d, REI 0h, Bee: L, Group 9B.* Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; *REI 12h, Bee: L.* Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

■ Squash Beetle (*Epilachna borealis*)

Squash beetle is a minor pest of cucurbits, and is generally limited to southern New England. Like its close relative the Mexican bean beetle, it is a leaf-eating member of the ladybeetle family. Adults overwinter in field edges. They have the typical ladybeetle shape and are 8 to 10 mm long, red-orange, with 12 black spots on their wing covers (elytra) and 6 on the thorax. The yellow egg clusters and yellow larvae covered with dark spines may be found on all cucurbit crops, in wild cucurbit weeds, and occasionally on lima bean, cowpea pods, or corn silk. Pupation takes place on the underside of the leaf or in nearby weeds. Feeding by adults and larvae creates round scars in leaves, leaving lacy veins intact. Adults can also produce spiral scars on the fruit which may render them unmarketable. The first generation eggs are plentiful in June, and the life cycle is completed in about 4 to 5 weeks. There is 1 generation per year in New England but 2 farther south. They are not strong fliers, so crop rotation to distant fields helps to limit colonization and populations. However, when production space is limited, they can build up until they become an economic pest. Harrowing down early summer squash and cucumber fields after harvest in July, when the beetles are still in the larval stage, will help limit populations. Row covers can exclude the beetles. In addition to those listed below, several common insecticides that are labeled for other pests of cucurbits will control squash beetle including spinosad, spinetoram, and pyrethrin.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; *PHI 1d, REI 24h, Bee: H, Group 3A.*

petroleum oil (Suffoil X): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed. For beetle larvae only. For pumpkin and squash only.

■ Squash Vine Borer (*Melittia cucurbitae*)

Squash vine borers (SVB) are day-flying moths, with bright orange markings on their backs and legs. They resemble wasps. Most eggs are laid on the stem within a foot of the soil. Hatching larvae tunnel into the stem and, if plentiful, cause wilting, reduce squash yields or even sever the stem from the roots. In rare cases when populations are very high, larvae may bore into fruit. The large cream-colored larvae are 1" to 1.5" long and 3/8" wide. The pupae survive the winter 1 or 2" deep in the soil. Spring or fall plowing buries pupae deep in the soil and reduces populations. Preferred hosts have thick stems, while thin-stemmed squash tend to be more resistant to attack. Yields of summer squash can be reduced by 33% if infestations exceed 5 larvae per plant. Pumpkins can sustain high infestations without yield reductions. Butternut squash are resistant to SVB. Monitor with a Scentry Heliiothis pheromone trap from early June through early August. Make 2 to 4 weekly applications if more than 5 moths per week are captured. Timing is very important. Treat base of stems thoroughly to target hatching larvae. Some selective materials used for other caterpillars in squash, such as spinosyns and *Bacillus thuringiensis aizawai*, have demonstrated efficacy in trials.

acetamiprid (Assail 30 SG): 5.3 oz/A; PHI 0d, REI 12h, Bee: M, Group 4A. Most effective on newly laid eggs and nymphs.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested to be effective.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28. Squash vine borer only.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

spinosad (Entrust^{OG}): 6 to 8 fl oz/A; PHI 3d, REI 4 h, Bee: M, Group 5.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Squash Bug (*Anasa tristis*)

Squash bug adults are grayish-brown, hard, flat-backed insects, 0.5" to 0.75" long, with long legs and antennae. Adults often hide around the base of the plant or under plastic mulch and are hard to target with sprays. Eggs are shiny, smooth, reddish-brown and seed-shaped and are usually deposited on the leaves in an organized, neatly-spaced pattern, in groups of 10 to 20. The soft-bodied nymphs are grey with dark-brown or black heads, antennae and legs. Adults survive the winter in natural and artificially-sheltered sites

along field margins or under plant debris within fields. Both adults and nymphs have needle-like mouthparts that they use to extract plant juices. The plant vascular system may become clogged, causing the plant to wilt, darken and die. They may also spread cucurbit yellow vine (CYV), a common Southwestern bacterial disease that has been found in a few isolated places in CT and MA.

Among cucurbits, the crops that are most susceptible and attractive to squash bug are yellow summer squash, zucchini, Hubbard, and pumpkin, especially thick-stemmed types. Watermelon, cucumber, muskmelon and butternut resist damage and also provide poor food quality for adult and nymph survival. Squash bugs are greatly reduced by crop rotation at least 1/4 mile from previous cucurbit crops. Clean cultivation also reduces the attractiveness of the crop, while use of mulches and reduced-tillage favors squash bug survival. Keep headlands mowed and free of trash to reduce overwintering sites. Systemic furrow, drip or seed treatments and sprays for cucumber beetle (including bifenthrin) at the seedling stage often control colonizing squash bug adults. Placing row covers at seeding or transplanting prevents access by squash bug until blooming, when covers need to be removed.

Scout undersides of leaves for squash bug adults and eggs and treat if egg masses exceed 1 per plant. Time squash bug sprays to kill young nymphs which are easiest to control. Thorough coverage is necessary. As this often coincides with the bloom period, treat late in the day to reduce risk to bees and select products with lower bee toxicity.

acetamiprid (Assail 30 SG): 5.3 oz/A; PHI 0d, REI 12h, Bee: M, Group 4A. Most effective on newly laid eggs and nymphs.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake. Foliar application for squash bug nymphs only.

azadirachtin & pyrethrins (Azera^{OG}): 16 to 56 oz/A foliar, drench, and greenhouse applications; PHI 0d, REI 12h, Bee: M, Groups un & 3A.

bifenthrin (Brigade* 2EC): 2.6 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 1 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A. Do not apply when foliage is wet. Apply sufficient spray volume for thorough coverage; time sprays for early morning or late afternoon. Repeated application may cause plant injury.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Do not apply to vegetables grown for seed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flupyradifurone (Sivanto): 10.5 to 14 oz/A; PHI 1d, REI 4h, Bee: L, Group 4D. Foliar applications only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 1d, REI 24h, Bee: H, Group 3A.

permethrin (Pounce* 25WP): 12.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

zeta-cypermethrin (Mustang*): 3 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

For more information on biology and management, see the two-spotted spider mite in the insect control section of Eggplant section.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; PHI 3d, REI 12h, Bee: L, Group 25.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A; PHI 7d, REI 24, Bee: H, Group 3. Control may be improved with addition of a non-ionic surfactant.

gamma-cyhalothrin (Declare*): 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A. Suppression only.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May require repeated applications. Use of a companion insecticide is recommended for enhanced and residual control.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L.

neem oil (Trilogy^{OG}): 0.5% to 2% solution in 25 to 100 gal water/A; PHI 0d, REI 4h, Bee: M, Group 18. Avoid mid-day applications and ensure good coverage.

petroleum oil (Suffoil X): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For pumpkin and squash only.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 23. Complete coverage is necessary; an adjuvant may be used to improve coverage and control. Effective against egg and nymphal stages.

■ Whiteflies

For more information, see whiteflies in insect control section of Tomato, Outdoor.

acetamiprid (Assail 30 SG): 2.5 to 5.3 oz/A; PHI 0d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 14 fl oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

beta-cyfluthrin (Baythroid* XL): 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Suppression only.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

Chenopodium extract (Requiem EC): 2 to 3 qts/A; PHI 0d, REI 4h, Bee: L. Apply before pests reach damaging levels.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 10 oz/A chemigation; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting, or drip chemigation during first half of crop growing cycle.

dinotefuran (Safari 20SG): 3.5 to 7 oz/100 gal; 7 to 14 oz/A; 0.16 to 0.32 oz/sq ft.; REI 12h, Bee: H, Group 4A. Squash transplants only, while in greenhouse. Not for use on field or greenhouse grown crops.

dinotefuran (Venom): 1 to 4 dry oz/A foliar or 5 to 7.5 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Do not apply to vegetables grown for seed.

fenpropathrin (Danitol* 2.4EC): 10.66 to 16 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2.8 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Suppression only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; 0.44 fl oz/10,000 plants on seedling transplants in greenhouse; PHI 21d, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection. Not for foliar applications.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May require repeated applications. Use of a companion insecticide is recommended for enhanced and residual control.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L.

petroleum oil (Suffoil X): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For pumpkin and squash only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Knack): 8 to 10 oz/A; PHI 7d, REI 12h, Bee: L, Group 7. Does not control adults. Apply when whiteflies reach economic threshold.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; *PHI 7d, REI 12h, Bee: M, Group 23.* Complete coverage is necessary; an adjuvant may be used to improve coverage and control. Effective against egg and nymphal stages.

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seed/seedling root zone during or after planting/transplanting or shanked into root zone after transplanting or establishment. Green Peach (*Myzus persicae*) and Melon (*Aphis gossypii*).

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ No-Till and Stale Seedbed

See Stale Seedbed Technique, page 107.

Based on work done in New York State, it may be possible to achieve good weed suppression by allowing winter rye to grow to 30", killing it with glyphosate (Roundup), and then seeding the pumpkins or squash with a no-till planter. Remember that if weed suppression is not adequate, cultivation will be very difficult in the rye stubble. Any of the herbicides registered for postemergence control can be used in no-till pumpkins to control weeds not suppressed by the killed cover crop.

See Stale Seedbed Technique, page 107. Prepare field 10 to 14 days prior to planting. Allow weeds to germinate. After seeding, but prior to crop emergence, then apply herbicides or flaming.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

paraquat (Gramoxone SL 2.0*): restricted use. Use 2-4 pts/A; *REI 12h, Group 22.*

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

bensulide (Prefar 4E): *REI 12h, Group 8.* Apply 5 to 6 qt/A. Can be preplant incorporated by shallow cultivation (1-2") or applied preemergence and incorporated by irrigation within 36 hours or application. Good for annual grass control. See label for rotation restrictions. Can be used under plastic mulches.

clomazone (Command 3ME): *REI 12h, Group 13.* Do not use on Jack-o-lantern pumpkins. Will control many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Combining with Curbit will also control pigweed species. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence or after transplanting. See label for

sensitive cultivars. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for replanting restrictions. For winter squashes, apply 0.67 to 2 pt/A prior to seeding or transplanting. For summer squashes, apply 0.67 to 1.33 pt/A prior to seeding or transplanting. Use the lower rate on coarse soils and the higher rate on fine soils.

Do not apply to soil that will be covered with plastic mulch. Apply to row middles between plastic covered beds as a preemergence soil surface treatment before transplanting at rates as noted above.

ethalfluralin (Curbit EC): *REI 24h, Group 3.* Can be used as a broadcast treatment. Do not use under mulches, row covers, or hot caps. May be banded between rows of plastic mulch. Do not soil incorporate prior to planting. Apply to seeded crop at time of seeding or up to two days after seeding, or apply as a banded spray between rows after crop emergence. A minimum of ½" of irrigation water (within two days after application) or ½" of rainfall (within five days of application) is required for activation. Use 3 to 4.5 pt/A, based on soil texture. Rate will vary with the soil texture and organic matter. See label for rate selection. Use during cold, wet weather can result in crop injury or stunting. Some varieties are susceptible to injury or yield loss.

ethalfluralin + clomazone (Strategy): *REI 24h, Group 3 and 13.* Use 2 to 6 pt/A, based on soil texture. See label for rate selection. Can be used as a broadcast treatment. Do not use under mulches, row covers, or hot caps. May be banded between rows of plastic mulch. Do not soil incorporate prior to planting. Apply to seeded crop at time of seeding or up to two days after seeding, or apply as a banded spray between rows after crop emergence. A minimum of ½" of irrigation water (within two days after application) or ½" of rainfall (within five days of application) is required for activation. Use during cold, wet weather can result in crop injury or stunting. Some varieties are susceptible to injury or yield loss.

s-metolachlor (Dual Magnum): This product has:

1. A full label that permits the use of Dual Magnum between rows of pumpkins.
2. An indemnified label for use over the top of pumpkins available in Massachusetts, Maine, and New Hampshire only
3. An indemnified label for use in Winter Squash available in Massachusetts, Connecticut, and New Hampshire only.

1. Full Label: *PHI 30d, REI 12h, Group 15.* Pumpkins only. Apply as a directed and shielded spray between the rows of plastic mulch or between bare ground rows in pumpkins to suppress or control annual grasses, yellow nutsedge, and certain annual broadleaf weeds including nightshade species. Apply before the weeds have emerged at 1.0 to 1.33 pt/A as an inter-row or inter-hill application in pumpkin. Leave 1 foot of untreated area over the row, or 6 inches to each side of the planted hill and/or any emerged pumpkin foliage. Use the lower Dual Magnum rate on soils light in texture (loamy sand or lighter) and low in soil organic matter (less than 3%). Dual Magnum applied as a broadcast spray over the planted row or hill, or applications made directly to crop

foliage will increase the risk of injury to the pumpkin crop such as stand loss, delayed maturity, and loss of yield. Will not control emerged weeds. Do NOT use Dual Magnum in winter squash, summer squash, or gourds.

2. Indemnified label for Pumpkin - MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. This is a restricted label available only to those growers who apply through the website and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.
3. Indemnified label for Winter Squash - MASSACHUSETTS, CONNECTICUT, and NEW HAMPSHIRE ONLY. This is a restricted label available only to those growers who apply through the website and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

■ Herbicides Used Pre- and Postemergence to Weeds

halosulfuron (Sandea): PHI 30d, REI 12h, Group 2. Use lower rates on lighter textured soils with low organic matter. Up to 2 application per year, not to exceed 2 oz/A total.

For pumpkins and winter squash: Apply 0.5 to 0.75 oz/A.

1. **Direct seeded, Preemergence:** Apply after planting, but prior to soil cracking.
2. **Direct seeded, Postemergence:** Apply after the crop has reached the 2 to 5 true leaf stage, preferably 4 to 5 true leaves, but before first female flowers appear.
3. **Pre-transplant:** Apply prior to transplant. Crop may be transplanted into this treated area no sooner than 7 days after application unless local conditions demonstrate safety at an earlier interval. Limit movement of Sandea treated surface soil during the transplanting process. If treated soil is moved into the transplant hole, injury can occur.
4. **Post-transplant:** Apply to transplants that are established, actively growing and in the 3 to 5 true leaf stage, no sooner than 14 days after transplanting unless local conditions demonstrate safety at an earlier interval. Apply before first female flowers appear. Sandea can be applied as an over-the-top application, a directed spray application or with crop shields to minimize contact of the herbicide with the crop.

For pumpkins, winter squash, summer squash, and gourds:

1. **Row Middle/Furrow Applications:** Apply 0.5 to 1 oz/A between rows of direct seeded or transplanted crop while avoiding contact of the herbicide with the planted crop. If plastic is used on the planted row, adjust equipment to keep the application off the plastic.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes

into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 14d, REI 24h, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): PHI 14d, REI 12h, Group 1. Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution. During periods of high temperature and/or high humidity some flowers may be damaged or dislodged and some foliar necrosis may result.

RADISH

Radish (*Raphanus sativus*) is a member of the Brassica family, along with cabbage and other cole crops. Radish is a very old crop, possibly important as early as 5,000 years ago. Present-day radishes include European radishes with relatively small roots as well as the large-rooted white daikons that are enjoyed both as food and, recently, as a cover crop, due to long taproots that can penetrate compacted soil.

Radish grows very quickly, maturing in 21-28 days under ideal conditions. The roots (technically swollen hypocotyls and roots) are spicy, due to the presence of glucosinolates, which are sulfur-containing compounds produced by members of the Brassica family. High temperatures and a lack of moisture can increase both pungency and the speed of bolting. As a result, production in the spring and fall often results in higher quality radishes than those produced in the

summer. Some varieties also have a tendency to become pithy, possibly in response to certain environmental conditions.

Types and Varieties

Table radishes come in an array of shapes (round, cylindrical, turnip-like) and colors (white, green, shades of red, and black). Daikon is a general term for a group of long, white radishes that need cool temperatures and short day lengths to flourish. Some of these can grow up to 18" long and weigh about 3 lb on average, but can reach almost 50 lb. The black or winter radish is intensely hot. The tuber of this biennial plant is formed from the basal part of the main shoot and a portion of the root. Shape, size, and skin color vary widely.

RADISH VARIETIES	
Small, Round	Slender
Altaglobe	d'Avignon (red and white)
Champion	French Breakfast (red and white)
Cherriette	White Icicle (white)
Cherry Belle	Daikon
Early Scarlet Globe	Discovery
Fireball	Summer Cross No. 3
Fuego	April Cross
Rover	Black
Ping Pong (white)	Nero tondo

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.0-6.8. Radishes need loose, well-drained soil for easy root expansion. Although daikon can penetrate heavy soils to depths more than one foot, the roots will not be smooth, uniform and tender in heavy soils. In stony or very heavy soil, shorter daikon varieties perform better. Because radish grows so rapidly, a rich, fertile soil is essential. They prefer cool growing conditions (50-65°F), so maintain a high level of soil moisture to minimize the adverse effects of summer. Hot weather reduces quality and increases pungency. Late plantings may bolt before edible roots form.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Seeding rate for table radish is 18-38 lb of seed/A (depending on variety); 1.4 oz/100 ft row. Seeding rate for daikon radish is 1 lb/A.

Spacing: Seed radish 0.25"-0.5" deep, spaced at 0.75"-1" apart within the row (to obtain 12-15 plants per foot of row). Space rows 8"-15" apart. Not recommended for transplanting.

In the spring, plant as soon as the soil can be worked; thereafter, plant at intervals of about 10 days. Soft, well-tilled ground will result in the most attractively-shaped radishes. Radishes are often planted in 4' wide raised beds, 6 rows per bed. Use of floating row covers at time of planting will help control flea beetles and cabbage root maggots. Keep moist, especially if growing in hot conditions.

Harvest and Storage

Yield: A good yield of bunched table radish is 2,500 dozen bunches (8-12 radishes/bunch) per acre (about 25 bunches per 30 ft of row). A good yield of film packed radishes (8 oz. bags) is about 15-20 bags per 30 ft of row. Daikon may be marketed in cartons or 20 lb plastic bags at 15-20 tons/A.

Table Radishes:

Harvest on time, beginning at about 3-4 weeks when roots are the size of a large marble (depending on variety). Bunch or top, hydrocool, and refrigerate. Topped radishes will keep 3-4 weeks in good, crisp condition if kept at 32°F, 95% RH, and in breathable packaging.

Daikon Radishes:

Harvest by hand beginning approximately 60 days after planting. The roots are harvested at about 12-14" in length for the processing market and 2.5" for the oriental vegetable market. Daikon can be sold with or without the tops attached; usually a better price is paid for tops left on the roots.

To store, bunch or top, hydrocool, and refrigerate. Topped radishes will keep 3-4 weeks in good, crisp condition if kept at 32°F, 95% RH, and in breathable packaging. Daikon will last 3-4 months in the same conditions.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Alternaria leaf spot

Alternaria leaf spot does not affect the root but will reduce the value of fresh-packed plants that retain the foliage. Buy certified disease-free seed or hot-water treat seed. Reduce cruciferous weeds and plow under crop debris in the fall. Rotate with non-cruciferous crops.

Plant Nutrient Recommendation According to Soil Test Results for Radish

RADISH	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate	50	150	100	25-50	0	125	100	50	0-25
TOTAL RECOMMENDED	50	150	100	25-50	0	125	100	50	0-25

Crops

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11.* Do not rotate with other strobilurin (Group 11) fungicides.

***Bacillus amyloliquefaciens* strain D747 (Double Nickel 55^{OG}):** 0.25 to 3.0 lb/A; *PHI 0d, REI 4h, Group 44.* Use sufficient water for thorough coverage. Begin application at crop emergence, transplanting or when conditions are conducive to disease development. Other formulations are available. See label for rates.

***Bacillus subtilis* Strain QST 713 (Serenade Max^{OG}):** 1.0 to 3.0 lb/A; *PHI 0d, REI 4h, Group 44.* Begin applications soon after emergence and when conditions favor disease. Apply in sufficient water to provide thorough coverage.

penthiopyrad (Fontelis): 16.0 to 30.0 fl oz/A; *PHI 0d, REI 12h, Group 7.*

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; *PHI 7d, REI 12h, Groups 9 & 12.*

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; *PHI 0d, REI 12h, Group 11.* Do not alternate with Group 11 fungicides such as Quadris.

■ Downy Mildew (*Hyaloperonospora parasitica*)

This disease occurs worldwide, affects most crucifers, and is most important at the seedling stage. It is an important pathogen on radish because it can infect the fleshy root, causing external black patches, lesions on the root shoulder, and internal grey or black flecking and streaking. The root surface is scarred, prone to cracking or splitting, and unmarketable. Manage downy mildew on transplants by improving air circulation and irrigating early in the day so plants can dry quickly. Plant resistant or tolerant cultivars.

■ Seed Decay

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

azoxystrobin (Quadris): 0.40 to 0.80 fl oz/1000 row feet; *PHI 0d, REI 4h, Group 11.*

***Bacillus amyloliquefaciens* strain D747 (Double Nickel 55^{OG}):** 0.125 to 1.0 lb/A; *PHI 0d, REI 4h, Group 44.* See label for at planting instructions and restrictions. Labeled for damping off, seedling blights, and root and crown rot. Other formulations available. See label for rates.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; *REI 12h, Group 12.* For protection against seed-borne and soil-borne fungi. Does not control Pythium or Phytophthora.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; *REI 48h, Group 43.* For Pythium control applied as banded spray. Application at seeding may help control downy mildew. See label.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lb seed; *REI 48h, Group 4.*

mefenoxam (Ridomil Gold SL): 1.0 to 2.0 pt/A; *REI 48h, Group 4.* Pre-plant incorporated or soil spray broadcast or band.

■ White Rust, White blister (*Albugo candida*)

Yield reductions are rare but quality is reduced by the prominent signs of the pathogen. On radish, white rust can

also infect flower shoots and cause root swellings. Use resistant cultivars where available and rotate to non-hosts where the disease is common. Proper fertility levels, especially of phosphorous and potassium, have been reported to reduce disease.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; *PHI 0d, REI 4h, Group 11.* Do not make more than one foliar application of Quadris before alternating with a non-group 11 fungicide.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 1.0 TO 2.25 lb/A; *PHI 0d, REI 48h, Group M1.* Begin application when disease first appears or when conditions favor disease.

pyraclostrobin (Cabrio EG): 8.0 to 16.0 oz/A; *PHI 0d, REI 12h, Group 11.* Do not rotate with other Group 11 fungicides.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Cabbage Maggot (*Delia radicum*)

The cabbage maggot can be controlled with spunbonded row covers. Cover at seeding and seal the edges with soil to exclude the cabbage maggot fly which lays eggs at the base of young radish seedlings. Do not plant into land that was planted to a cole crop the previous year as this pest overwinters as pupae in soils where larvae infested plants.

See the Cabbage section for more information about cabbage maggot and for more on cultural controls.

chlorpyrifos (Lorsban 4E): Pre-plant: 5.5 pint/A ; At or post-plant: 1 oz/1000 row ft.; *PHI 30d, REI 24h, Bee: H, Group 1B.* Apply pre-plant as a broadcast spray and incorporate same day into top 2 to 4" of soil, or apply as a water-based drench in seed furrows with the seed at planting in a minimum of 40 gal/A total drench.

cyantraniliprole (Verimark): 10 to 13.5 oz/A; *PHI 0d, REI 4h, Bee: H, Group 28.* For soil applications at planting. Supplemental label.

■ Cutworms

See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

Bacillus thuringiensis aizawai (XenTari^{OC}): 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

Bacillus thuringiensis kurstaki (Dipel DF^{OC}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 21d, REI 12h, Bee: H, Group 3A. Apply as foliar spray.

carbaryl (10% Sevin Granules): 20 lb/A; PHI 7d, REI 12h, Bee: H, Group 1A. Apply evenly over soil surface.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

methoxyfenozide (Intrepid 2F): 8 to 16 oz/A; PHI 14d, REI 4h, Bee: L, Group 18. Suppression only.

spinosad (Seduce^{OC}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 3d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

■ **Flea Beetle, Crucifer (*Phyllotreta cruciferae*) and Striped (*P. striolata*)**

See the Cabbage section for more details on flea beetles that attack brassica crops.

Nonchemical control: Row covers provide protection. See Cabbage Maggot section, above, and Slitted and Floating Row Covers section.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 5.1 to 6.4 oz/A; PHI 21d, REI 12h, Bee: H, Group 3A. Apply as foliar spray.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A PHI 7d, REI 12h, Bee: H, Group 1A.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 7d, REI 12h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 4.4 to 10.5 oz; PHI 21d soil, REI 12h, Bee: H, Group 4A. For soil applications only.

kaolin (Surround WP^{OC}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression/repellence only. Generally compatible as a tank mix with other insecticides.

petroleum oil (Suffoil X^{OC}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. For beetle larvae only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 6 to 8 oz/A; PHI 3d, REI 4h, Bee: M, Group 5. Suppression only.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A; PHI 3d, REI 4h, Bee: M, Group 5.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 7d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 6.5 oz/A; REI 12h, Bee: H, Group 4A. Use at seeding or within 24 hours of seeding as an in-furrow or narrow surface band with sufficient water for incorporation, or in drip irrigation.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

See Soil Fumigation Outdoors, page 89. Proper use of Vapam can provide weed control and will be more economical if multiple plantings are used.

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

trifluralin (Treflan HFP): REI 12h, Group 3. Apply 1 to 1.5 pt/A as a preplant soil incorporated treatment. Select rate based on soil texture; see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Especially effective for annual grass.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 15d, REI 24h, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications

permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 32 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

RHUBARB

Rhubarb, genus *Rheum*, has a long history of medicinal use in Asia. Its use as a food crop appears to be much more recent, with widespread table use beginning in the 19th century. The leaves of the plant are toxic, but the fattened petioles are consumed most commonly in pies and other sweetened desserts, in beverages, and occasionally as a vegetable. Several species of *Rheum* exist, and modern culinary varieties were likely derived from crosses between some combination of these species. The genus *Rheum* is not closely related to other vegetable crops; it belongs to the family *Polygonaceae*, along with buckwheat and many weeds including sorrels and knotweeds.

Rhubarb is a perennial that requires a dormant winter period below 40°F to stimulate vigorous spring growth. It grows most vigorously in cool conditions, and growth is suppressed at high temperatures (>90°F). For this reason, rhubarb is adapted to Northern latitudes in the U.S. and Canada. Once established, a rhubarb planting can remain productive for 8-15 years.

Types and Varieties

Rhubarb varieties are classified as red, green, or speckled (pink). The market generally prefers red over green or speckled.

In New England, the most common variety grown is Macdonald, also known as Macdonald's Canadian Red or Macdonald Crimson. This cultivar has large stalks and a vigorous and upright-growing habit, and is resistant to wilt and root rot. It is probably the most common variety available. It is excellent for pies, canning, and freezing. It can have medium to heavy seed stalk production. At the beginning of the harvest season, late May, the petioles may be a deep red but will lose some or all of their color as the weather warms and as harvest extends through June into early July.

Red types: Crimson (may also be called Crimson Cherry, Crimson Red, or Crimson Wine). This is reportedly the only variety of consequence in Oregon and is reported to do well in New England. It produces brightly colored red stalks with the unique characteristic of being red throughout. Other vigorous red varieties include Valentine and Cherry Red.

Speckled types (pink): Victoria produces large stalks of excellent quality, long, round with smooth ribs. It develops pink speckling on a light green stalk with the pink color being more intense at the bottom of the stalk, fading to a solid green near the top. Victoria is commonly used for forcing. Strawberry is very similar to Victoria, and may be the same variety. German Wine is similar to Victoria but slightly more vigorous and more intense in color, typically with a darker pink speckling on a green stem.

Green types: Riverside Giant is a cold-hardy, vigorous producer with large diameter, long, green stalks.

For more information on varieties, see the Varieties chapter of "The Rhubarb Compendium."

RUTABAGA AND TURNIP

Turnip (*Brassica rapa*) is a fresh market root vegetable that reaches maturity about 50-70 days after planting. Turnip leaves (eaten as greens) are usually pubescent (hairy) and light to medium green in color. Turnip roots generally have little or no neck and a distinct taproot. Best quality results when the crop reaches edible size under moderately cool temperatures.

Rutabaga (*Brassica napa, napobrassica* group) is commonly known as yellow turnip or swede. It is thought to be a cross between turnip (*B. rapa*) and wild cabbage (*B. oleracea*) and developed in central Europe. The leaves are bluish in color, thick like cabbage leaves, and smooth. Rutabagas have short necks with leaf scars, and they require about a month longer to mature than turnips. In northern New England, rutabagas are more popular than turnips. If planted early in the spring, rutabagas will be of poor quality (woody and tough). For best quality, plant from mid-June to mid-July in northern to southern New England, respectively, timing harvest to occur in the cool weather of fall after a few light frosts.

Types and Varieties

Rutabaga and Turnip Varieties	
Turnip	Rutabaga
All Top (for greens)	American Purple Top
Hakurei (white salad type)	Laurentian (Thompson strain)
Purple Prince	Macomber Turnip (popular in Southeastern MA)
Purple Top White Globe	
Scarlet Queen Red Stem (red salad type)	
Topper (for greens)	
White Lady	

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8.

Turnip following other vegetables in the same season may not require the application of additional fertilizer as turnip is an efficient scavenger of residual nutrients.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Rutabaga: Seed to 4"-8" within rows and 30" between rows 0.25" deep. This requires 1.5-2 lb of seed per acre (about 1/4 oz per 100 feet of row).

Turnip: Seed to 2"-3" within rows and 14"-18" between rows 0.5" deep. This requires about 6 lb of seed per acre (or about 0.33 oz/100 ft row.)

Harvesting and Storage

Mature turnips are harvested when the roots are about 2" in diameter. For highest quality, rutabagas should be harvested when they are 3"-5" in diameter at the top end and weigh 2-3 lb. Rutabagas and turnips can be stored for long periods at 32°F and at a relative humidity of 90%-95%. Chilling improves the flavor of rutabagas by aiding the conversion of starch to sugar, reducing strong or bitter flavor.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Leaf Spots (*Alternaria* and *Cercospora*)

Leaf spot fungi do not infect the root but infection can reduce yield, and blighted foliage can reduce the value of fresh-packed plants. To help reduce leaf spot, buy hot-water treated seed, reduce weeds and plow under crop debris in the fall.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides.

***Bacillus amyloliquefaciens* strain D747 (Double Nickel 55^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4h, Group 44. Applied as foliar spray. See label for application methods and instructions.

***Bacillus subtilis* strain QST713 (Serenade Max^{OG}):** 1.0 to 3.0 lb/A; PHI 0d, REI 4h, Group 44.

copper hydroxide (Kocide 3000): 0.5 to 0.75 lb/A; PHI 0d, REI 48h, Group M1. Not labeled for rutabaga.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 7d, REI 12h, Groups 9 & 12.

penthiopyrad (Fontelis): 16.0 to 30.0 fl oz/A; PHI 0d, REI 12h, Group 7.

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; PHI 0d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

■ Black Leg (*Phoma* Leaf spot and canker)

From foliar lesions, the pathogen spreads into leaf veins to the petioles and eventually the main stem. On root crops, such as rutabaga and turnip, a dry rot of the bulb or hypocotyl develops. The neck and shoulder areas have large, brown lesions, and an extensive dry rot deep into the fleshy tissue develops. Severely affected bulbs become shriveled and dry, and are often invaded by secondary fungal and bacterial decay organisms. Start with certified or treated seed, or treat seed with hot water or fungicides. Rotate to non-susceptible crops. Promptly incorporate infected crop debris after harvest. Eliminate cruciferous weeds which can act as hosts. Apply foliar fungicides to protect susceptible cultivars (see Leaf Spots above).

■ Seed Decay and Damping-Off

azoxystrobin (Quadris F): 0.4 to 0.8 fl oz/1000 row ft.; PHI 0d, REI 4h, Group 11. For *Rhizoctonia* root rot control applied as in-furrow application. See label for restrictions.

***Bacillus amyloliquefaciens* strain D747 (Double Nickel 55^{OG}):** 0.125 to 1.0 lb/A; PHI 0d, REI 4h, Group 44. See label for application methods and instructions.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* or *Phytophthora*. Use as seed treatment prior to seedling.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; REI 48h, Group 43. Apply for *Pythium* root rot control as banded spray. Application at seedling may help control downy mildew.

mefenoxam (Ridomil Gold SL): 1.0 to 2.0 pt/A; REI 48h, Group 4. Pre-plant incorporated or soil spray broadcast or band).

■ White Rust, White blister (*Albugo candida*)

Yield reductions are rare but quality is reduced by the prominent signs of the pathogen. On radish, white rust can also infect flower shoots and cause root swellings. Use resistant cultivars where available and rotate to non-hosts where the disease is common. Proper fertility levels, especially of phosphorous and potassium, have been reported to reduce disease.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Do not alternate with another Group 11 fungicide.

copper hydroxide (Kocide 3000): 0.5 to 0.75 lb/A; PHI 0d, REI 48h, Group M1. Not labeled for rutabaga. An organic formulation is available.

Plant Nutrient Recommendation According to Soil Test Results for Rutabaga and Turnip

RUTABAGA AND TURNIP	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O ₅ per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate	50	150	100	25-50	0	100	75	25	0
TOTAL RECOMMENDED	50	150	100	25-50	0	100	75	25	0

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 1.0 to 2.25 lb/A; *PHI 0d, REI 48h, Group M1.* Labeled for rutabaga and turnip.

pyraclostrobin (Cabrio EG): 8.0 to 16.0 oz/A; *PHI 0d, REI 12h, Group 11.* Do not rotate with other Group 11 fungicides.

INSECT CONTROL

Nonchemical control: Flea beetles, leafminers and the cabbage maggot can be controlled in spring crops with spunbonded row covers. Cover at seeding and seal the edges with soil to exclude the cabbage maggot fly, which lays eggs at the base of the young turnip or rutabaga seedlings. Rotate fields so that flies do not emerge under row covers. Row covers are most effective for spring crops. Use a non-heating row cover, such as Proteknet, to protect fall turnips and rutabagas from cabbage maggot during August and early September, as spunbonded row covers can trap too much heat and cause reduced yield and root quality. Aphids are generally kept below damaging levels by natural enemies. If using row cover, do not place over crops with aphids present as the cover will exclude natural enemies and cause outbreaks of aphids under the cover.

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphid, primarily Cabbage Aphid (*Brevicoryne brassicae*)

See cabbage aphid in the Cabbage section. Green peach aphid is an occasional pest of rutabaga and turnip; see Green Peach Aphid in the Pepper section for more information.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; *PHI 0d, REI 4h, Bee: L, Group un.* When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 21d, REI 12h, Bee: H, Group 3A.* For use on turnip greens only.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

dimethoate (Dimethoate 4EC): 8 oz/A; *PHI 14d, REI 48h, Bee: H, Group 1B.* For turnip greens and roots only.

dinotefuran (Venom): 2 to 3 oz/A foliar; *PHI 1d, REI 12h, Bee: H, Group 4A.* For turnip greens only.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; *PHI 3d, REI 12, Bee: L, Group 9C.*

flupyradifurone (Sivanto): 7 to 10.5 oz/A for foliar application. 7 to 14 oz/A for soil application on turnip greens only; *PHI 7d foliar, PHI 1d soil, REI 4h, Bee: L, Group 4D.*

imidacloprid (Admire Pro): 4.4 to 10.5; *PHI 21d, REI 12h, Bee: H, Group 4A.* For soil applications only.

malathion (Malathion 57EC): 1 to 1.6 pt/A rutabaga, 1 to 2 oz/A turnip; *PHI 7d rutabaga, PHI 1d turnip, REI 12h, Bee: H, Group 1B.*

pymetrozine (Fulfill): 2.75 oz/A; *PHI 7d, REI 12h, Bee: L, Group 9A.* Turnip greens only.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

sulfoxaflor (Transform WG): 0.75 to 1.5 oz/A; *PHI 7d, REI 24h, Bees: H, Group 4C.*

thiamethoxam (Actara): 1.5 to 3 oz/A; *PHI 7d, REI 12h, Bee: H, Group 4.*

thiamethoxam (Platinum): 5 to 12 oz/A; *REI 12h, Bee: H, Group 4.* Systemic insecticide used at seeding or within 24 h of seeding as an in-furrow or narrow surface band with sufficient water for incorporation, or in drip irrigation.

■ Cabbage Maggot

See Cabbage section for more information on cabbage maggot. Both spring and fall crops are susceptible to maggot damage. Cooler soils in early fall allow survival of eggs from late-season maggot fly. Use drop nozzles directed to base of plant. Use at least 100 gal water/A.

chlorpyrifos (Lorsban* 4E): Pre-plant: 4.5 pint/A ; At or post-plant: 1.6 to 2.75 oz/1000 row ft (turnip) or 1.6 to 3.2 oz/1000 row ft (rutabaga); *PHI 30d, REI 24h, Bee: H, Group 1B.* Apply pre-plant as a broadcast spray and incorporate same day into top 2 to 4" of soil, or apply to direct seeded crops as a 4" band over the row at planting time. May be applied to transplanted turnips as spray directed to base of plants immediately after setting. Do not add adjuvants or apply as a foliar spray.

diazinon (Diazinon* AG500): 2 to 4 qt/A; *REI 4d, Bee: H, Group 1B.* Broadcast and incorporate to a depth of 4 inches just before planting. For rutabaga only.

Foliar Treatment for Adult Flies:

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): REI 12h, Group 9.

paraquat (Gramoxone SL 2.0*): Restricted use. Use 2.5-4 pts/A; REI 12h, Group 22. Turnip only.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

DCPA (Dacthal 75WP): PHI 25d, REI 12h, Group 3. Turnip only. Apply 6 to 14 lb/A at seeding. Will not control ragweed, galinsoga or smartweed. Use lower rates on sandy soils. This product may not be registered for use on turnip in the future. Always make sure to check the current label before using.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 30d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

clpyralid (Stinger): PHI 30d roots, PHI 15d for tops, REI 12h, Group 4. Turnip only. For postemergence control of weeds in the composite and legume families, such as common ragweed, galinsoga, prickly lettuce, sweet clover, and wild buckwheat and postemergence suppression of sowthistle infesting turnip harvested for roots and tops. Stinger is very effective on small seedling annual and emerging perennial weeds less than 2" to 4" tall, but is less effective and takes longer to work when weeds are larger. A single application of 1/3 to 1/2 pt/A is permitted. Application timing is based on targeted weeds; see label for details. Spray additives are not needed or required by the label and are not recommended. Stinger is a postemergence herbicide with some soil residual activity. Observe replant restrictions on the label or injury may occur from herbicide carryover.

pelargonic acid (Scythe): PHI 1d, REI 12h, Group 17. Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will

cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

SALAD MIX

Salad mix, mesclun mix and spring mix are interchangeable terms used to describe assorted mixed greens harvested at the seedling stage (3-4 weeks). Blends usually include 5-7 types of greens with a range of leaf sizes, colors, shapes and textures. Although leaf lettuces are often the primary component, most mixes also include non-lettuce greens, most commonly *Brassica* species, to add diversity in flavor and appearance. Mixes can be mild or spicy flavored, and can be harvested young for use in salads or older as "braising" mixes for stir-fries.

Brassica crops typically contribute spicy or pungent flavors, while the lettuces and Chenopodium crops are mild and sweet. Chicory family crops are slightly bitter, and along with some herbs, contribute different flavors. Varieties are selected not only for flavor and leaf texture, but also for color. Red varieties that are well suited for salad mix production are those that develop good red color even under low light conditions. For cool-weather or winter production, use the most cold-hardy species such as spinach, Claytonia (Miner's Lettuce), arugula, kale, and other brassicas. For late fall and winter production, growers should choose lettuce and spinach cultivars with resistance to a wide array of races of downy mildew.

Types and Varieties

LETTUCES	Red Salad Bowl, Parris Island Cos, Rouge d'Hiver, Lolla Rossa, Tango, Red Sails, New Red Fire, Defender, Outredgous
BRASSICA FAMILY	Tatsoi, Kyona/Mizuna, Komatsuna, Broccoli Raab, Tokyo Bekana, Scarlett Frill, Green Wave and other mustards (<i>Brassica juncea</i>), Red Russian Kale (<i>B. napus</i>), Cress (various species), Arugula/Rocket (<i>Eruca sativa</i>), Chinese Cabbage (<i>B. rapa</i>), Broccoli Raab
CHENOPODIUM FAMILY	Swiss Chard (Ruby Red, Fordhook Giant), Spinach (Space, Tyee), Beet (Golden, Chioggia, Red), Amaranth
CICHORIUM FAMILY	Radiccio, Endive, Escarole
HERBS	Dill, Cilantro, Fennel, Basil, Parsley, Salad Burnet Chervil
OTHER	Mache/Corn Salad (Valerianella), Dandelion (Taraxacum), Purslane and Claytonia/Miners's Lettuce (Portulaca)

Soil Fertility

Salad mix crops are short season and require relatively little fertilizer (see Nutrient Table, next page). Sidedressing is usually not needed. If planted following another crop, additional fertilizer for salad mix may not be necessary.

Planting

Salad mixes are typically seeded at high density. Seeding rates vary with seed size and the species, but common spacing is less than 1" between plants with 2"-3" between rows on 30" wide beds. Seed can be broadcast, but is often seeded 1-6

rows at a time using a hand-driven precision seeder. For larger scale production, 17-row mechanical seeders are often used. Germination may take anywhere from 2 to 15 days at the optimum germination temperature (55°-70°F). Follow specific germination requirements for each component of the mix. Generally, salad mix components are cool season crops that will germinate poorly when night temperatures are 80°F or higher. Germination of some species can be inhibited by heat and light, shading may be necessary to get adequate germination and growth in mid-summer.

Although seeds of multiple varieties or species can be blended and planted together, different germination times and rates of growth make coordination difficult. Each component of a mix is typically grown separately and mixed after harvesting. Salad mix is made from short-season crops (30-40 days), but the rate of growth varies greatly with species, day length, total light and temperature. The time from planting to harvest will be 2-3 times longer for fall (September to February) plantings than for late spring or early summer plantings. Consistent harvest throughout the growing season requires carefully planned succession plantings. Winter production in New England is possible, but low light and cool temperatures make production time longer than in summer, and cold-hardy species should be used. Prolonged exposure to temperatures below freezing (32°F) will reduce the quality of even the hardiest species. The best way to determine timing is to experiment in your own system, but for recommendations for a starting point see these two publications from Johnny's Selected Seeds: Salad Mix Production <https://www.johnnyseeds.com/on-demandware.static/-/Library-Sites-JSSSharedLibrary/default/dw6508102b/assets/information/salad-mix-production.pdf>, and the Winter Growing Guide <https://www.johnnyseeds.com/growers-library/vegetables/winter-growing-guide-high-tunnel-scheduling.html>.

Harvest and Storage

Greens can be harvested from 3 to 5 weeks after seeding. Flavors intensify and leaf textures change with age, so optimum harvest time will depend on yields required and the intended use of the final mix. Harvesting can be done by hand clipping approximately 1" above the soil line. Mechanical or hand-driven saw-like harvesters with or without vacuums are used for large-scale production. Some varieties will re-grow to permit multiple harvests, but the second harvest will be less uniform and may be of lower quality. For this reason, most growers harvest each planting only once. After harvest, salad mix components are washed, dried and cooled prior to packaging in bags or plastic-lined boxes. Young leaves are tender and susceptible to bruising, and therefore must be handled very gently after harvest. Rapid cooling with near-freezing water will greatly prolong

shelf life. Greens are then dried using small salad spinners or custom-made commercial or homemade versions with larger capacity. Salad mix should be stored as close to 32°F as possible with 98-100% relative humidity. Food safety issues from microbial contamination are often linked to leafy greens that are eaten raw. It is important to follow some basic practices that are in accord with the guidance outlined in the Food Safety section of this guide.

DISEASE CONTROL

The different crops that make up salad mix may or may not be susceptible to the same group of diseases. For additional disease control information, refer to the section of this guide relating to the specific plant family.

Since salad mix is harvested prior to maturity, diseases that affect mature crops often do not pose problems. However, high planting densities may increase likelihood of other problems. For example, fungal diseases that usually don't infect young plants (e.g., downy mildew and Rhizoctonia in lettuce) often become a problem in mesclun production because of the high humidity and plant populations. Chemical control options are limited because of the very short pre-harvest interval and the diversity of plant families that may be included in the mix. When treating salad mix, make sure that chemicals are labeled for all of the crop species in the mix.

INSECT CONTROL

The different crops and crop families that make up salad mix may or may not be susceptible to the same insect pests. Pests that may occur in salad mix include aphids, whiteflies, cabbage looper, diamondback moth, flea beetles, and leafminers. When insects or damage is observed, note which crop or crops are affected, and refer to the sections of this guide relating to that specific crop or plant family. Use preventative and cultural control options where possible. Chemical control options are limited because of the very short pre-harvest interval and the diversity of plant families that may be included in the mix. When treating salad mix, make sure that chemicals are labeled for all of the crop species in the mix.

WEED CONTROL

The best suggestion for weed management in salad mix is use of the Stale Seedbed Technique. Glyphosate (Roundup), paraquat (Gramoxone Inteon), and pelargonic acid (Scythe) are registered for stale seedbed use. Flaming can also be used. Salad mix is usually planted thick and often out-competes weed growth after stale beds are used. Prepare the seedbed at least 2 to 3 weeks prior to planting so that weeds have adequate time to emerge. After crop emergence keep cultivations shallow to protect crop roots. Do not move soil into the crop row as lettuce plants may be more susceptible to diseases when soil is mounded against the stems of the crop.

Plant Nutrient Recommendation According to Soil Test Results for Mesclun

MESCLUN	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	50	180	120	30-60	0-30	180	120	30-60	0
Sidedress 3-4 Weeks after Planting (if needed)	30	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	50-80	180	120	30-60	0-30	180	120	30-60	0

SPINACH

Spinach is a hardy cool weather crop, grown for use as a cooked green vegetable or for salad greens. Temperature for optimum production and high quality is 55°-60°F with day length of approximately 12 hours. Winter spinach production in unheated high tunnels has grown in New England to supply year round greens. Under certain conditions, spinach will bolt (develop a seed stalk and flower), reducing quality. During summer months, high temperatures and long days will result in bolting. For spinach plants overwintered in high tunnels, bolting may occur in early spring as days lengthen. The tendency to bolt varies with the cultivar, some being more resistant than others. Growers who want greens in summer should consider beet greens and/or Swiss chard as substitutes, since they produce well under high temperature and long day conditions.

Types and Varieties

There are two main types of spinach: smooth leaf and savoy (crinkled leaf). Both grow equally well and are marketed similarly, but the savoy type, because of its crinkled leaf, is more difficult to clean. Asian leaf types are relatively smooth with pointed leaves.

Spinach Varieties	Type	Season	Resistances
Acadia	semi-savoy	SF	DM1-13, 15, 16
Carmel	semi-savoy	SF	DM1-11, 13
Corvair	smooth	W	DM1-11, 13
Emporer	semi-savoy	SFW	DM1-1-
Escalade	semi-savoy	SF	DM1-14, 16
Flamingo	asian	SFW	DM1-11, 12, 13
Pigeon	smooth	W	DM1-13
Gazelle	smooth	F	DM1-13
Giant Winter OP	semi-savoy	DW	DM1-11
Kookaburra	semi-savoy	SF	DM1-13
Marabu RZ	semi-savoy	SF	DM1-10, CMV
Palco	semi-savoy	SF	DM1-5, 8-9, 11-12, 14
Red Kitten	smooth	SFW	DM1-13, 15
Reflect	semi-savoy	SFW	DM1-11
Regiment	semi-savoy	SFW	DM1-7, 11
Renegade	smooth	SFW	DM1-7, CMV
Samish	savoy	FW	DM1-4
Santorini	semi-savoy	SFW	DM1-7
Seaside	smooth	S	DM1-12, 14
Shelby	smooth	SF	DM1-13, 15, 16
Space	smooth	FWS	DM1-3, 5, 6, 8, 11, 12, CLS
Unipak 151	semi-savoy	SFW	DM1-4, CMV
Whale	smooth	SF	DM1-7
Winter Bloomsdale OP	savoy	W	CMV
Woodpecker	smooth	SF	DM1-15
Yukon	semi-savoy	W	DM1-12, 14, 15

OP = open-pollinated, Seasons: S = spring, F = fall, W = winter.
Resistant or tolerant to: DM: Downy Mildew (races indicated), CMV: Cucumber Mosaic Virus, CLS: Cladosporium leaf spot

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8. Soils with low pH will result in slow growth and chlorotic leaves.

Because of sensitivity to magnesium deficiency, older spinach leaves may tend to show yellow color similar to that caused by nitrogen deficiency or downy mildew. Low levels of magnesium in the soil can be corrected by using high magnesium lime (dolomitic) or by adding magnesium to the fertilizer. Do not automatically apply more nitrogen to try to develop the desired deep green color. Rather, make a topical application of 10-15 lb magnesium sulfate (Epsom salts) in 100 gal water. Spray to wet the foliage.

If magnesium was deficient, you will see a color change to dark green overnight. Spinach will accumulate excess nitrates if nitrogen is used in an attempt to induce green color. It is always best to check for magnesium problems before applying extra nitrogen if plants have chlorotic pale green color or yellow lower leaves.

In winter production, there may be 6 contiguous months of harvest from one crop, therefore sidedressing may be necessary. Nitrogen use efficiency of crops is less in cold temperatures, so more frequent sidedressing of small amounts of N will achieve better results than fewer sidedresses of larger amounts of N. Avoid putting fertilizer directly onto crop foliage.

Less nitrogen fertilizer will be needed if legume sod was plowed down or if manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

Planting

Seed will germinate at soil temperatures of 32°-60°F. Soil temperatures above 70°F will result in poor germination. Another cause for poor germination is salt accumulation in the top 0-2" of heavily composted high tunnels. Priming the seed may improve germination. Spinach seed is short-lived and susceptible to damping-off. For good stands start with new, fungicide-treated seed each year.

For direct-seeded spinach, the desired plant stand is 6-8 plants per foot of row and 12" between rows. This requires 8-10 lb of seed per acre (1/2-1 oz per 100 feet of row). After preparing a stale seedbed, seeds may also be broadcast for a denser planting to help control weeds. During dry conditions, irrigation may be necessary to germinate seeds. Seed 0.25"-0.5" deep depending on soil moisture and temperature. Deeper planting is suggested in a warm dry soil. Growers should attempt to seed to a stand as thinning is generally not recommended.

Spinach can also be germinated in seed trays and transplanted at the desired site. This method is particularly useful if the site is not yet prepared for the next crop, and to get a head-start in production. Seedlings are typically ready for transplant approximately three-weeks after initial seeding. Using this method, desired plant spacing is 3-4 plants per square foot, or an equivalent plant spacing of 6" x 6".

Field Culture

Main season (spring and fall). Spinach can be seeded in the spring as soon as the soil can be worked. Sandy soils are

generally preferred because they warm earlier in the spring. Two main crops are generally grown, one in the spring, another in late summer, seeded about 6 weeks before the average first frost.

Winter. Winter production of spinach by New England growers is now quite popular. Stand-alone low tunnels equipped with heavyweight row cover (1.25oz/yd²) and plastic (6mil) result in good winter survival of spinach and allow for separate fall and spring harvests. However, accessing plants during winter months when the ground is frozen is challenging, and leaves may not be saleable during this this period.

High tunnel production permits winter access and provides additional insulation, and can result in winter-long harvests if plants are established by late fall. Within high tunnels, plants should be covered with a single or double layer of floating rowcover (>0.55oz/yd²) and/or a low tunnel.

For overwintering spinach, particularly in northern areas, plants should be established by early-November. If direct seeding, a September seeding date is suggested. However, germination can be poor in tunnels with warm soil temperatures (>70°F). Transplanting seedlings instead of direct seeding can help mitigate this risk, and ensures a good stand for winter production.

Plant growth slows with less than 10 hours of light per day starting around November 10th in Southern RI and October 30th in Northern ME. Aim to have 4-5 true leaves on plant before you reach this point.

Highest total yields (fall through spring) will be obtained by the earliest fall planting dates, primarily due to higher fall production. Spring-only yields (January to April) are less affected by fall planting date.

It is important to ensure adequate moisture is available for spinach during the fall, winter, and spring months, either by using drip or overhead irrigation. However, cool humid conditions can result in downy mildew, and thus it is important to choose varieties with downy mildew resistance for winter culture.

In high tunnels, there are three common physiological disorders that may occur on winter-grown spinach. Freezing damage can kill and brown leaf tissue. This can be minimized by using secondary row covers or low tunnels inside high tunnels. Oedema results when water pressure causes cells to burst, resulting in scab-like calluses on the leaves. This can be minimized by limiting irrigation and managing relative humidity as temperatures drop and growth slows. Lastly, under winter and spring conditions, spinach often forms natural leaf structures (glandular trichomes) on upper and

lower leaf surfaces, which resemble tiny water droplets or insect eggs, but actually arise from the leaf surface on tiny stalks. These trichomes often cause concern, but are harmless.

Harvest

Spinach is usually harvested from 37 to 45 days after seeding, but can take much longer to mature during late fall and winter months.

In summer and fall, harvest early in the day and cool immediately to maximize shelf life (10-14 days). In the winter, frozen leaves can be damaged during harvest, so delay harvest until later in the day after leaves have thawed.

Good yields for fresh market will range from 5 to 7 tons/A and 10-12 tons/A for processing. In winter high tunnel production, growers report producing 0.4-0.6 lbs/sq ft. Spinach is sometimes field packed loose into crates or cartons. Whole plants are sometimes bunched, like carrots, when going directly to retail markets. Package as bushel baskets or crates containing 20-25 lb, cartons or wire-bound crates with 2 dozen bunches each, or loose leaf 12 film bags (10 oz per bag) in a master carton. Winter spinach is often sold bagged in smaller quantities.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ⁰⁶ indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Cladosporium Leaf Spot (*Cladosporium variable*)

Cladosporium leaf spot caused by *Cladosporium variable* is considered to be of minor importance in spinach crops, but can be severe in spinach seed production and has become a problem in high tunnels. The most conducive environment for disease development is cool and moist with temperatures between 59° and 68°F and relative humidity above 80%. However, the fungus can grow under a wide range of temperatures, ranging from 41° to 86°F. The epidemiology of this disease is not well known. Spinach seeds carry the fungus, but it has not been determined whether the disease is transmitted via contaminated seed to soil or seedlings. It is also not known how long the fungus can survive on spinach residues in soil or in weed hosts. *Cladosporium* has been recovered from dried leaves and seed stocks up to eight years old.

Plant Nutrient Recommendation According to Soil Test Results for Spinach

SPINACH	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	60-80	180	120	30-60	0-30	180	120	30-60	0
Sidedress 3-4 Weeks after Planting	30	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	90-110	180	120	30-60	0-30	180	120	30-60	0

Cultural controls rely mainly on sanitation—the removal of infected plants, spinach debris, spinach volunteers, and unused seed. Start with certified, disease-free seed or treat seed with hot water or bleach to reduce seedborne inoculum. There are difference in cultivar susceptibility with ‘Winter Bloomsdale’ more resistant than ‘Fall Green’ and ‘Ozarka’.

***Bacillus mycoides* isolate J (LifeGard WG^{OG}):** 1.0 to 4.5 oz/A; PHI 0d, REI 4h, Group P6. Apply at first true leaf stage or after thinning. Refer to label for other appropriate rates and application volumes.

■ Downy Mildew (*Peronospora farinosa*)

Downy mildew is considered the most important disease of spinach and is favored by cool, moist conditions. Incidence of the disease appears to be increasing due to the increased use of high tunnels for spinach production. The potential overlap of field spinach and high tunnel spinach can create a “green bridge” for the disease, allowing the pathogen to transfer between field and high tunnels. The pathogen will not survive without a live host. Reducing humidity and leaf wetness along with the use of resistant varieties will minimize the incidence of the disease. There are several races of the pathogen with Race 14 recently surfacing in New England high tunnels. Downy mildew management relies on resistant varieties (select resistance to Races 1-15 if possible) and once infected, there is little that can be done. Rotate out of spinach for at least two years.

acibenzolar-S-methyl (Actigard 50WG): 1.0 to 0.75 oz/A; PHI 7d, REI 12h, Group 21.

ametocradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 0d, REI 12h, Groups 45 & 40.

azoxystrobin (Quadris): 12.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Rotate with a fungicide other than a strobilurin. Quadris can be phytotoxic to spinach. See label for precautions.

***Bacillus amyloliquefaciens* strain D747 (Double Nickel LC^{OG}):** 0.5 to 6.0 qt/A; PHI 0d, REI 4h, Group 44.

copper hydroxide (Kocide 3000): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Flecking may occur.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Flecking may occur. See label for precautions.

cyazofamid (Ranman 400SC): 82.75 fl oz/A; PHI 0d, REI 12h, Group 21.

cymoxanil (Curzate 60 DF): 5.0 oz/A; PHI 1d, REI 12h, Group 27. Use only in combination with a protectant fungicide.

famoxadone plus cymoxanil (Tanos): 8.0 to 10.0 oz/A; PHI 1d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason): 5.5 to 8.2 fl oz/A; PHI 2d, REI 12h, Group 11.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. Must be used in a tank mix with a fungicide with a different mode of action.

fluxapyroxad + pyraclostrobin (Merivon): 6.0 to 11.0 fl oz/A; PHI 1d, REI 12h, Groups 7 & 11. For suppression only. Do not apply as tank mix with other pesticides or anything other than water (for spinach).

fosetyl aluminum (Aliette WDG): 2.0 to 5.0 lb/A; PHI 3d, REI 12h, Group 33. Lower rate of 2-3lb/A may be used when tank mixed with fungicide labeled for downy mildew (do not mix with copper). See label for instructions.

mandipropamid (Revus): 8.0 fl oz/A; PHI 1d, REI 4h, Group 40. Addition of adjuvant is recommended.

mefenoxam (Ridomil Gold SL): 0.25 pt/A; PHI 21d, REI 48h, Group 4. Must be applied pre- and post-plant for effective control of downy mildew. Incorporate into soil mechanically or with irrigation. See label for instructions and precautions.

oxathiapiprolin (Orondis Gold 200): 4.8 to 9.6 fl oz/A; PHI 0d, REI 4h, Groups 49. Apply to soil in-furrow and/or via drip irrigation.

oxathiapiprolin plus mandipropamid (Orondis Ultra): 5.5 to 8.0 fl oz/A; PHI 1d, REI 4h, Groups 49 & 40. Apply with an adjuvant.

phosphorous acid (Fosphite): 1.0 to 3.0 qt/100 gal; PHI 0d, REI 4h, Group 33. Do not apply to plants that are heat or moisture stressed or recently treated with copper products.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11. May cause leaf injury. Do not apply with anything other than water. See label for precautions.

■ Seed Decay

Buy treated seed. Do not use treated seed for food, feed or oil purposes.

fludioxonil (Maxim 4FS): 0.08 to 0.16 oz/100 lb seed; REI 12h, Group 12. For protection against seed-borne and soil-borne fungi. Does not control *Pythium* and *Phytophthora*.

mefenoxam (Apron XL): 0.085 to 0.64 fl oz/100 lb seed; REI 48h, Group 4. For *Pythium* damping-off protection. Do not use in greenhouse or enclosed environments. See label for restrictions.

thiram (Thiram 42 S): 8.0 lb/100 lb seed; REI 12h, Group M3.

***Streptomyces grievoviridis* strain K61 (Mycostop^{OG}):** 0.08 oz/lb seed; REI 4h, Group NC. Other methods of application listed on label.

■ *Stemphylium* Leaf Spot (*Stemphylium botryosum*)

This new disease of spinach was first detected in California in 2001. It affects both production spinach and spinach seed crops, and has become a problem in high tunnel production. Details on the pathogen’s life cycle are lacking, although the pathogen is seedborne. In the field, the disease spreads slowly and damage is limited. Cultural controls rely mainly on sanitation—the removal of infected plants, spinach debris, spinach volunteers, and unused seed. Start with certified, disease-free seed or treat seed with hot water or bleach to reduce seedborne inoculum.

***Bacillus mycoides* isolate J (LifeGard WG^{OG}):** 1.0 to 4.5 oz/100 gal water/A; PHI 0d, REI 4h, Group P6.

■ White Rust (*Albugo occidentalis*)

A very damaging disease of spinach that is found only east of the Rocky Mountains in the USA. Plant resistant cultivars and practice crop rotation. Apply preplant and foliar fungicides.

acibenzolar-S-methyl (Actigard 50WG): 0.5 to 0.75 oz/A; PHI 7d, REI 12, Group 21.

azoxystrobin (Quadris): 6.0 to 15.5 fl oz/A; PHI 0d, REI 4h, Group 11. Quadris may be phytotoxic to spinach. See label for precautions.

copper hydroxide (Kocide 3000): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Flecking may occur on spinach leaves.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 0.75 to 1.25 lb/A; PHI 0d, REI 48h, Group M1. Flecking may occur. See label for precautions.

cyazofamid (Ranman 400 SC): 2.75 fl oz/A; PHI 0d, REI 12h, Group 21.

famoxadone plus cymoxanil (Tanos): 8.0 to 10.0 oz/A; PHI 1d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action. Do not alternate or tank mix with other Group 11 fungicides.

fenamidone (Reason 500SC): 5.5 to 8.2 fl oz/A; PHI 2d, REI 12h, Group 11.

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. Must be used in a tank mix with a fungicide with a different mode of action.

mefenoxam (Ridomil Gold SL): 0.25 pt/A; PHI 21d, REI 48h, Group 4. Must be applied pre- and post-plant for effective control of white rust. Incorporate into soil mechanically or with irrigation. See label for instructions and precautions.

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A. May cause crop injury under certain conditions. Do not apply as tank mix with anything other than water. See label for precautions.

■ Cucumber Mosaic Virus (CMV)

CMV is found worldwide and infects over 800 crop and weed hosts. This disease is transmitted by aphids in a nonpersistent manner; insecticides are of no value in controlling this disease. Start with virus-free seed. Eliminate weeds such as chickweed, pokeweed, and milkweed. Grow resistant varieties such as Blight Resistant Savoy, Savoy Hybrid 612 and Melody.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, primarily Green Peach Aphid (*Myzus persicae*)

Aphids found in spinach are primarily green peach aphid (see Pepper section for more information). Thresholds used in other regions may apply and include 1 aphid/plant on seedlings and 4 to 10 aphids per plant on older plants. Natural enemies often provide control. Use selective products to conserve natural enemies.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Versys): 1.5 fl oz/A; PHI 0d, REI 12 h, Bee: L, Group 9D.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For control of green peach and suppression of potato aphid only.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz.; PHI 1d, REI 12 h, Bee: H, Group 28.

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 0d, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A for foliar application, 21 to 28 oz/A for soil application; PHI 1d foliar, PHI 21d soil, REI 4h, Bee: L, Group 4D.

imidacloprid (Admire Pro): 1.3 oz/A foliar, 4.4 to 10.5 oz/A soil; PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. For foliar applications, apply only to fully leafed-up canopies.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with a companion labeled insecticide; for green peach aphid, must use companion insecticide.

malathion (Malathion 57EC): 1.6 pt/A; PHI 7d, REI 12h, Bee: H, Group 1B.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9B. Translaminar. Apply when aphids first appear, before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; PHI 3d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; PHI 3d, REI 12h, Bee: H, Group 4C.

tolfenpyrad (Torac): 17 to 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A. Except lettuce aphids.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Aphid control may be variable depending on species present and host-plant relationships.

■ Blister Beetles

See Blister Beetles in the Beets and Swiss Chard section for more information on blister beetle life cycle and management. A single spot spray with a broad-spectrum insecticide registered for caterpillars on spinach will control the beetles.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

■ Cabbage Looper (*Trichoplusiani*) and Fall Armyworm (*Spodoptera frugiperda*)

See Cabbage section for more information on cabbage looper and Sweet Corn section for more information on fall armyworm.

***Bacillus thuringiensis aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A for looper, 0.5 to 2.0 lb/A for armyworms; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A looper, 1 to 2 lb/A armyworm; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.4 oz/A for CL, 2.4 to 3.2 oz/A for FAW; PHI 0d, REI 12h, Bee: H, Group 3A. For FAW, controls first and second instar larvae only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; PHI 40d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetiva): 12 to 17 oz/A; PHI 7d, REI 12h, Bee: L, Groups 16 & 28.

carbaryl (Sevin XLR Plus): 1 to 2 qt/A; PHI 14d, REI 12h, Bee: H, Group 1A. For FAW only.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied to soil at planting, through drip chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone. For CL and beet armyworm only.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 10 to 17 oz/A loopers, 13.5 to 20.5 oz/A armyworm; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Cabbage looper only.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A for armyworm, 3.2 to 4.8 oz/A for looper; PHI 7d, REI 12h, Bee: H, Group 6.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A for CL, 3.5 to 6 oz/A for BA; PHI 3d, REI 12h, Bee: H, Group 22. For CL and beet armyworm only.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 7d, REI 48h, Bee: H, Group 1A. Do not apply if minimum daily temperature is less than 32°F. Do not apply to seedlings less than 3" in canopy diameter. Cabbage loopers may be resistant.

methoxyfenozide (Intrepid 2F): 4 to 10 oz/A; PHI 1d, REI 4h, Bee: L, Group 18. Use lower rates when plants are small or infestations are light.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils. Cabbage looper only.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 3 to 6 oz/A looper, 4 to 8 oz/A armyworm; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant.

tebufenozide (Confirm 2F): 6 to 8 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Use low rate for early season applications to young, small plants. Use of an adjuvant is recommended.

tolfenpyrad (Torac): 21 oz/A; PHI 1d, REI 12h, Bee: H, Group 21A. Suppression of armyworm only.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Leafminer, Beet and Spinach

See Leafminers in Beet and Swiss Chard section for more information on the life cycle, scouting, and management of beet and spinach leafminers.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un.* Leafminer larvae only.

bifenthrin (Brigade* 2EC): 2.1 to 6.4 oz/A; *PHI 40d, REI 12h, Bee: H, Group 3A.*

chlorantraniliprole (Coragen): 5.0 to 7.5 oz/A; *PHI 1d, REI 4h, Bee: L, Group 28.* May be applied to soil at planting, through drip chemigation and as a foliar spray. For soil applications, must be applied uniformly in the root zone.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.* Do not use adjuvants in tank mix with Exirel in spinach.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; *PHI 0d, REI 4h, Bee: H, Group 28.* For soil applications at planting.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; *PHI 1d, REI 4h, Bee: H, Group 28.*

cyromazine (Trigard): 2.66 oz/A; *PHI 7d, REI 12h, Bee: M, Group 17.*

dinotefuran (Venom): 1 to 3 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 7d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip.

emamectin benzoate (Proclaim*): 3.2 to 4.8 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6.* Suppression only.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. May need to make repeated applications. For enhanced and residual control, apply with a companion labeled insecticide.

permethrin (Pounce* 25WP): 6.4 to 12.8 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

spinetoram (Radiant SC): 6 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Efficacy improves with the addition of an adjuvant.

spinosad (Entrust SC^{OG}): 6 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Do not apply to seedlings for transplant. Control may be improved with addition of an adjuvant.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107, for information on the use of these herbicides.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

cycloate (Ro-Neet): *REI 48h, Group 8.* Not for use in Vermont, Connecticut or Rhode Island. Apply 1/2 gal/A in 10 to 50 gallons of water per acre. Must be immediately incorporated into the soil to a depth of 2-3" to prevent loss of the herbicide. Crop should be planted or seeded immediately after application. Use lower rate during hot weather and/or dry soil conditions. Can be applied preplant incorporated, or at planting. To reduce the risk of crop injury, apply and incorporate 7 to 10 days before planting, then rework soil at planting. Use on sandy mineral soils only, but may cause crop injury on very light sandy soil. Works by interfering with seed germination and seedling development. Will not control existing weeds.

s-metolachlor (Dual Magnum): *REI 12h, Group 15.* MASSACHUSETTS, MAINE, and NEW HAMPSHIRE ONLY. This is a restricted label available only to growers who register through the website and agree to a waiver of liability. Main target weeds for this registration are galinsoga and yellow nutsedge. All label instructions will be supplied after the application for use is completed. Once on the farm assist web site, click products at top left, then indemnified labels. Create a username and password, select Dual Magnum, and the crop.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 14d, 24hr REI, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 16 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

clopyralid (Stinger): *PHI 21d, REI 12h, Group 4.* For postemergence control of weeds in the composite and legume families. Apply to spinach in the 2- to 5-leaf stage and weeds are young and actively growing. Common annuals include galinsoga, ragweed, pineappleweed, clover, and vetch. Perennial weeds controlled include Canada

thistle, goldenrod species, aster species, and mugwort (wild chrysanthemum). Stinger is very effective on small seedling annual and emerging perennial weeds less than 2" to 4" tall, but is less effective and takes longer to work when weeds are larger. Some leaf curling may be observed on smaller spinach, particularly at higher use rates. Crop tolerance may be optimized by selecting the lower application rate necessary for weed control, especially where non-uniform emergence has caused variable plant sizes. Use 0.25 to 0.5 pt/A. Can use up to two applications per year, but can not exceed 0.5 pt/A per year. Spray additives are not needed or required by the label and are not recommended. Stinger is a postemergence herbicide with some soil residual activity. Observe replant restrictions on the label or injury may occur from herbicide carryover.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): *PHI 15d, REI 12h, Group 1.* Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Use with crop oil concentrate (2.0 pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. For beets, maximum 2.5 pt/A per application, minimum 14-days between applications. Do not exceed 5 pt/A per year. For chard, maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 3 pt/A per year. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

SWEET POTATO

Despite its name, the sweet potato is not related to Irish or white potato. Sweet potato belongs to the morning-glory family (*Convolvulaceae*). Sweet potato originated in South America and is one of the most important food crops in the developing world. Sweet potatoes are not the same as yam, although they are often marketed as such. True yams are in the family *Dioscoreaceae*, and are grown in tropical regions

such as Africa and the Caribbean. Sweet potato is a frost-sensitive crop that needs a frost-free growing season ranging from 90 to 100 days (depending on variety) to produce harvestable roots.

Types and varieties

The skin of sweet potatoes can be yellow, orange, copper, red, or purple; the flesh can be white, yellow, orange, or purple. Varieties with copper-colored skin with moist orange-colored flesh (e.g. Beauregard, Covington) are the most common in New England; however, some markets prefer the starchier white-fleshed varieties.

Sweet Potato Varieties	
Orange-fleshed	White-fleshed
Beauregard	Japanese
Covington	O'Henry
Carolina Ruby - deep red, thick skin	Japanese - purple skin, white flesh

Soil Fertility

Sweet potato will grow at a soil pH of 4.5-7.5, but 5.8-6.2 is optimal. Well-drained, loam soils result in large and well-shaped roots. When grown in heavy clay soils, or in soils with high soil organic matter, sweet potato may produce rough, irregular roots.

Sweet potato does not need high levels of nitrogen (N), and yields may be reduced if nitrogen exceeds 75 pounds/A. If manure or compost is added, be careful not to add excessive fertilizer-N. Nutrients should be applied according to soil tests. See fertilizer table below. Sweet potato needs high levels of phosphorous (P, up to 200 lbs/A) and potassium (K, up to 300 lbs/A). Both P and K can be applied at planting and N can be split between application at planting and before plants begin to run. Drip irrigation can be used to apply supplemental N under plastic mulch. Alternatively, all N can be applied at planting and covered with plastic mulch to prevent leaching.

Sweet potato requires more boron than many vegetables. On boron-deficient soils, 0.5 lb B/A (5 pounds Borax or 2.6 pounds Solubor) should be added to prevent a disorder called blister. This disorder is characterized by small, raised bumps on the root surfaces and plant stunting.

Planting

Sweet potatoes are grown from rooted sweet potato sprouts (slips) or vine cuttings. Slips can be produced by placing roots in warm (75°-80°F) moist sand or soilless media until sprouts are produced (about 1 month or longer). Slips are then pulled from the bedded roots and planted. In southern areas of the

Plant Nutrient Recommendation According to Soil Test Results for Sweet Potato

SWEET POTATO	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Soil Test Results									
Broadcast and Incorporate	25	200	120	30-60	0-30	300	200	50-100	0-50
Sidedress When Vines Start to Run	25-50	0	0	0	0	0	0	0	0
Sidedress 6-8 Weeks after Planting	0	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	50-75	200	120	30-60	0-30	300	200	50-100	0-50

US, larger growers produce their own slips. It is recommended for New England that slips be purchased from companies that provide certified disease-free slips.

Field planting begins when all chance of frost has passed. Soil temperature in the production field should reach at least 65°F at a 4" depth for 4 consecutive days before transplanting.

Rows are 32"-42" apart with in-row spacing 8"-12", depending on cultivar. Slips are transplanted into the rows at a depth of 3" with no less than 2 plant nodes in the ground and leaving 2 leaves or more above the ground. If slips do not have good root development, transplanting during cloudy weather and maintaining adequate field moisture just after transplanting will help ensure success.

Field Culture

Because of their vulnerability to wireworms, sweet potatoes should not be grown the first year after incorporating sod.

Research in New England has shown that yields are increased, particularly during cooler summers, by using raised beds covered with black plastic mulch.

Harvest and Storage

Sweet potato roots continue to grow until the leaves are killed by frost or until soil temperatures fall consistently below 65°F, whichever comes first. Time of harvest is often determined by digging up a few representative plants and determining the percentage of roots in the size classes. When tops of the plants turn black after the first frost, it is imperative to harvest as quickly as possible regardless of root size.

Sweet potato roots are very susceptible to damage at harvest. The roots do not have a thick protective outer layer of cells such as that on white potato tubers. Abrasions and wounds can lead to rots in storage.

Curing immediately after harvesting is recommended. This minimizes damage and loss during storage by healing harvest wounds. To cure, maintain roots in temperatures between 80°F and 86°F and a high relative humidity (85%-95%) for 4-7 days. This forms a corky periderm layer below the damaged areas which limits microbial invasion and water loss. A freshly harvested sweet potato is more starchy than sweet. During curing and storage, starches in the sweet potato are converted to sugars, improving flavor. Wait at least 3 weeks after harvest before consuming the roots to permit the starches to convert to sugars for maximum eating quality.

Sweet potatoes can maintain excellent quality for more than a year in proper storage conditions. The ideal storage conditions for sweet potato are the same as for winter squash; moderately warm (55°-60°F) at 60%-75% relative humidity.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Prevention is essential for disease control in sweet potato. The most important diseases are root diseases which become systemic; once infected it is not possible to cure the plant. Vegetative propagation is an ideal vehicle for disease perpetuation. Start with healthy propagating stock and inspect frequently in the production cycle. Planting stock should be produced and stored separately from commercial sweet potatoes. Careful handling and proper curing at harvest are primary disease prevention measures. Application of fungicides and bactericides are not as effective as proper curing in controlling post-harvest diseases. Practice good sanitation of farm equipment, storage bins, and storage rooms.

■ Rhizoctonia Root Rot and Stem Canker

azoxystrobin (Quadris): 0.4 to 0.8 fl oz/1000 row feet; *PHI 14d, REI 4h, Group 11*. Apply in-furrow or banded applications over row. Rotate with a fungicide with a different mode of action.

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A. May cause crop injury under certain conditions. Do not apply as tank mix with anything other than water. See label for precautions.

thiabendazole (Mertect 340F): 107.0 fl oz/100 gal water or 8.0 fl oz/7.5 gal water; *REI 12h, Group 1*. Dip the seed roots in the suspension for 1 to 2 minutes and plant immediately. Do not use treated seed roots as food or feed.

■ Black Rot (*Ceratocystis fimbriata*)

One of the most significant diseases of sweet potato, black rot is the common name for the decay of fleshy roots and symptoms on sprouts and vines. Successful control of black rot depends on selection of healthy seed roots, fungicide treatment, crop rotation, proper curing, and effective sanitation.

thiabendazole (Mertect 340F): 107.0 fl oz/100 gal water or 8.0 fl oz/7.5 gal water; *REI 12h, Group 1*. Dip the seed roots in the suspension for 1 to 2 minutes and plant immediately. Do not use treated seed roots as food or feed.

■ Soft Rot (*Rhizopus*)

Careful handling and proper curing at harvest are primary disease prevention measures. Application of fungicides and bactericides are not as effective as proper curing in controlling post-harvest diseases. Practice good sanitation of farm equipment, storage bins, and storage rooms.

dichloran (Botran 75 W): 1.0 lb/100 gal water; *REI 12h, Group 14*. Apply at bedding as a root dip or postharvest spray. Do not plant tomatoes as follow-up crop. See label for details.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, primarily Green Peach Aphid (*Myzus persicae*)

For more information see green peach aphid in the Pepper section.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

Beauveria bassiana (Mycotrol ESO): 8 to 32 oz/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application, 0.4 to 0.6 oz/100 lbs seed for seed-piece application; PHI 14d, REI 12h, Bee: H, Group 4A.

cyantraniliprole (Verimark): 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. For suppression of green peach aphid only.

flonicamid (Beleaf 50SG): 2 to 2.8 oz/A; PHI 7d, REI 12, Bee: L, Group 9C.

flupyradifurone (Sivanto): 7 to 10.5 oz/A; PHI 7d, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; PHI 7d foliar, PHI 125d soil, REI 12h, Bee: H, Group 4A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfill): 2.75 to 5.5 oz/A; PHI 14d, REI 12h, Bee: L, Group 9A. Selective control of aphids. Translaminar. Apply before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spirothram (Movento): 4 to 5 oz/A; PHI 7d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A. Foliar applications only; PHI 7d, REI 12h, Bee: H, Group 4C.

thiamethoxam (Actara): 3 oz/A; PHI 14d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 8 oz/A; REI 12h, Bee: H, Group 4A. Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer before or during planting, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

■ Cutworms

See cutworms in the Pepper and Tomato (Outdoor) sections for more information on the black and variegated cutworms.

alpha-cypermethrin (Fastac* EC): 1.3 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

Bacillus thuringiensis aizawai (XenTari^{OG}): 0.5 to 1.5 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with Bt kurstaki products (Dipel).

Bacillus thuringiensis kurstaki (Dipel DF^{OG}): 0.5 to 2 lb/A; PHI 0d, REI 4h, Bee: L, Group 11. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with Bt aizawai products (XenTari).

beta-cyfluthrin (Baythroid* XL): 0.8 to 1.6 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

carbaryl (10% Sevin Granules): 20 lb/A; PHI 7d, REI 12h, Bee: H, Group 1A. Apply evenly over soil surface.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 5 to 8 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

methoxyfenozide (Intrepid 2F): 6 to 10 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Suppression only.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 7d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

zeta-cypermethrin (Mustang*): 1.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Flea Beetle, Sweet potato (*Chaetocnema confinis*)

Sweet potato flea beetles feed only on the plant family that includes sweet potato, bindweed (*Convolvus* spp.), morning glory (*Ipomea* spp.), and also the Asian leafy green crop

known as water spinach (*Ipomea aquatica*) which is grown only with a state permit in MA because it is a noxious weed in southern states. Adults are small (1.5 to 1.8mm) black flea beetles with a bronze cast. Like many flea beetles, they overwinter as adults and become active in spring. They lay eggs primarily in bindweed, where larvae feed on roots, and pupate in the soil. There is one generation per year. In sweet potato, adults cause damage primarily to young plants, feeding in long narrow strips on the foliage, parallel to veins, rather than the small round holes that are characteristic of most flea beetle species. Damage is rarely severe enough to require controls. Larvae rarely feed on sweet potato, but may damage fibrous roots or etch channels into the surface of tubers. Some sweet potato varieties have greater resistance to root injury. Because sweet potato acreage is increasing in New England, cultural practices such as crop rotation and eliminating bindweed are especially important to prevent insects that feed on sweet potato and related plants from building up and becoming significant pests.

acetamiprid (Assail 30SG): 1.5 to 2.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

alpha-cypermethrin (Fastac* EC): 1.8 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 3.2 to 9.6 oz/A at cultivation or lay-by, 2.1 to 6.4 oz/A foliar; PHI 21d, REI 12h, Bee: H, Group 3A. May be applied as a soil-incorporated broadcast, bed or t-band spray into planting furrow to control sweet potato flea beetle only. May be applied as foliar spray to control all adult flea beetles.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 7d, REI 12h, Bee: H, Group 1A.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

chlorpyrifos (Lorsban 4E): 4 pint/A; PHI 125d, REI 24h, Bee: H, Group 1B. Apply as pre-plant broadcast spray and incorporate into top 4" to 6" of soil.

clothianidin (Belay): 2 to 3 oz/A for foliar application, 9 to 12 oz/A for soil application; PHI 14d, REI 12h, Bee: H, Group 4A.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 0d, REI 4h, Bee: H, Group 28. For soil applications at planting. Suppression only.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 3d, REI 12h, Bee: H, Group 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; PHI 7d foliar, PHI 125d soil, REI 12h, Bee: H, Group 4A.

kaolin (Surround WP^{OG}): 25 to 50 lb/A or 0.25 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression/repellence only. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

thiamethoxam (Actara): 1.5 to 3 oz/A; PHI 14d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 8 oz/A; PHI 12h, Bee: H, Group 4A. Systemic insecticide applied to seed pieces in-furrow during planting, impregnated on dry granular fertilizer before or during planting, or as directed spray at plant emergence or during last hilling operation. Must incorporate into root zone with sufficient irrigation within 24 hours. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 1.9 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Tortoise Beetle

There are several species of tortoise beetles which feed on sweet potato and related plants in the morning glory (*Convolvulaceae*) family and have a broad geographic range. These leaf-feeding beetles cause foliar damage in both adult and larval stages. Adults have a distinctive rounded shape, with their head and thorax covered and flattened often translucent margins on their wings and thorax, giving them the appearance of a turtle shell. Coloration is often bright and metallic, especially in the golden tortoise beetle (*Charidotella bicolor*). Adults overwinter and lay eggs in late spring and early summer; larvae feed on underside of leaves, and when full grown, pupate attached to the leaf. Larvae are flattened, adorned with branched spines, and construct a protective dried mass of cast skin and feces attached to their posterior end, which is held over their back. Their distinctive feeding holes are round, irregular and scattered across the leaf. There is one generation per year. Unless the numbers are very high, sweet potato outgrows the damage without yield loss.

chlorantraniliprole & lambda-cyhalothrin (Besiege*): 6 to 9 oz/A; PHI 14d, REI 24h, Bee: H, Groups 28 & 3A.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 1.28 to 1.92 oz/A; PHI 7d, REI 24h, Bee: H, Group 3A.

■ Slugs

Damage appears as shredded foliage. Look for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours. Grow plants away from moist, shaded habitats, use clean cultivation, control weeds, hand pick/crush slugs or scatter baits on the ground near infested plants. See the Cabbage section for more information on slugs.

iron phosphate (Sluggo: Snail and Slug Bait^{OG}): 20 to 44 lb/A; PHI 0d, REI 0h, Bee: L, Group 9B. Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; REI 12h, Bee: L. Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

■ Whiteflies

For more information see whiteflies in the Tomato section.

Chromobacterium subtsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

flupyradifurone (Sivanto): 10.5 to 14 oz/A; *PHI 7d, REI 4h, Bee: L, Group 4D.*

gamma-cyhalothrin (Declare*): 1.54 oz/A; *PHI 7d, REI 24h, Bee: H, Group 3A.* Suppression only.

imidacloprid (Admire Pro): 1.2 oz/A for foliar application, 4.4 to 10.5 oz/A for soil application; *PHI 7d foliar, PHI 125d soil, REI 12h, Bee: H, Group 4A.*

novaluron (Rimon 0.83EC): 12 oz/A; *PHI 14d, REI 12h, Bee: L, Group 16B.* Most effective on immature stages.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

spiromesifen (Oberon 2SC): 8 to 16 oz/A; *PHI 7d, REI 12h, Bee: M, Group 23.* Immature whiteflies only.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 7d, REI 24h, Bee: M, Group 23.* Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 4.25 to 5.76 oz/A; *PHI 7d, REI 12h, Bee: H, Group 4C.* Silverleaf and sweet potato whiteflies only. Foliar applications only.

■ Wireworms and White Grubs

See the Potato section for more information on wireworms. These root pests are favored by low, heavy soils that have been in sod or pasture. Delay planting susceptible crops, such as corn, potatoes or sweet potatoes, on such land for at least 2 years after the sod has been broken.

bifenthrin (Brigade* 2EC): 9.6 to 19.2 oz/A at-plant, for corn and tobacco wireworms only. 3.2 to 9.6 oz/A at cultivation or lay-by, or 2.1 to 6.4 oz/A foliar, for southern potato wireworm only; *PHI 21d, REI 12h, Bee: H, Group 3A.* May be applied as soil-incorporated broadcast, bed, or t-band spray into planting furrow or soil-directed and incorporated spray at cultivation or lay-by for wireworms and white grubs. May be applied as foliar spray for click beetle (adult wireworm) and May/June beetles (adult white grubs).

chlorpyrifos (Lorsban 4E): 4 pint/A; *PHI 125d, REI 24h, Bee: H, Group 1B.* Apply as pre-plant broadcast spray and incorporate into top 4" to 6" of soil. Wireworms only.

ethoprop (Mocap* 15G): 20 to 26 lb/A, or 1.6 to 2.1 lb/1,000 row feet; *REI 48h, Bee: H, Group 1B.* Apply in a 12"-15" wide band, 2 to 3 weeks prior to planting. Mix in top 2" to 4" of soil right after application.

Isaria fumosorosea Apopka Strain 97 (PFR-97 20% WDG^{OG}): 1 to 2 lb/A soil drench; *PHI 0d, REI 4h, Bee: M, Group M.*

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

Plastic mulch is recommended for sweet potato culture. It is important to maintain good weed control between the mulched rows before the plants run because once they do run access will be limited. Also, weedy areas between rows may harbor voles and wireworms.

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): *REI 12h, Group 9.*

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22.* Use 1-2 pts/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

clomazone (Command 3ME): *PHI 95d if < 3.3 pt/A used, PHI 125d if > 3.3 pt/A used, REI 12h, Group 13.* Use the lower specified rate on coarse soils and the higher specified rate on fine soils. Refer to the soil texture chart on label. Can be applied to the soil surface prior to planting at 1.3 to 4.0 pt/A, or post-transplant to the crop and prior to weed emergence at a maximum of 4.0 pints per acre. Will control annual grasses and many broadleaf weeds including common lambsquarters, velvetleaf, and jimsonweed. Some temporary crop injury (partial whitening of leaf or stem tissue) may be visible after crop emergence. Complete recovery will occur from minor early injury without affecting yield or earliness. See label for replanting restrictions.

DCPA (Dacthal 75WP): *REI 12h, Group 3.* Select rate for preemergence use based on soil type and weeds targeted for preemergence control. Good control of most annual grasses; fair on redroot pigweed, lambsquarter, and purslane. Apply to weed-free soil; will not control existing weeds. Can be applied at transplanting and/or at layby. Can be sprayed directly over transplants without injury. Lay by applications can be made up to 6 weeks after transplanting. If weeds emerge prior to layby, the onions should be cultivated or weeded prior to application. Preplant incorporation not recommended.

flumioxazin (Valor SX): *REI 12h, Group 14.* Do not use on any sweet potato variety other than "BEAUREGARD", unless user has tested Valor SX on other variety and has found crop tolerance to be acceptable. Apply up to 3 oz/A to soil prior to transplanting sweet potatoes slips for the preemergence control of weeds. Do not use greenhouse grown transplants. Do not use transplants harvested more than 2 days prior to transplanting.

napropamide (Devrinol 2-XT): *REI 12h, Group 15.* Apply 2 to 4 qt/A. Use the lower rate on light soil (coarse-textured - sandy) and the higher rate on heavy soils (fine textured

- clay). Apply to the soil surface after transplanting and wet the soil to a depth of 2" to 4" within 24-72 hours to activate.

■ Herbicides Used Postemergence to Weeds

carfentrazone (Aim EC): REI 12h, Group 14. Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to row middles of emerged crops with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): PHI 30d, 24hr REI, Group 1. Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

fluzifop (Fusilade DX): PHI 14d, REI 12h, Group 1. For grass weed control only. Apply up to 12 oz/A. See label to select rate based on grasses targeted for control. Allow for minimum 14 days between applications, and not to exceed 48 oz/A per year. Apply to actively growing grasses (see product label for susceptible stage). Add either crop oil concentrate (0.5-1%, 0.5-1 gallon per 100 gallons of spray) or nonionic surfactant (0.25-0.5%, 1-2 qt per 100 gal of spray).

TOMATO, GREENHOUSE AND HIGH TUNNEL

Tomato is the most widely grown high tunnel and greenhouse vegetable crop because of strong consumer demand for its high-value fruits, and because of its ability to utilize the vertical growing space and to maintain production over a relatively long harvest period. In New England, tomato yield and quality are usually greatly improved when growing in protected culture compared to the field. Greenhouse tomatoes are grown in a wide range of structures from simple hoop-houses and high tunnels to more expensive greenhouses with permanent foundations and sophisticated environmental controls. Regardless, the horticultural principles are the same.

Types and Varieties

Some growers plant field tomato varieties in tunnels, but the majority of varieties used in larger, more expensive structures are those bred specifically for greenhouse production. In general, these varieties are indeterminate, bred for sustained production over many months when pruned to a single stem, and have some tolerance to common greenhouse diseases such as leaf mold. Greenhouse beefsteak varieties include: **Geronimo**, **Rebelski** and **Trust**. Field varieties commonly grown in tunnels include BHN 589, **Big Dena** and **Big Beef**. Many growers also produce cherry, cluster and heirloom tomatoes in greenhouses and tunnels. Rootstock varieties used for grafting include **Maxifort** (very vigorous) and **Estamino** (less vigorous).

Fertility and Growing Media

To obtain sufficient quantity and quality of yield to justify the expense of greenhouse tomato production, careful attention must be paid to the growing medium. There are different approaches to production: soil vs. soilless culture and in-ground vs. container culture. With any system, the physical environment of the medium must promote good root growth. Nutrient supply must be optimized and maintained to encourage healthy plants and good fruit production.

The benefit of crop rotation holds true with in-ground systems, but not with soilless or hydroponic systems where the media is entirely replaced each growing season. In the latter, all containers should be sterilized before the next crop. Many growers do not rotate in-ground tomato crops from year to year because the greenhouse is designed specifically for that crop; in this case, sanitation is especially important. Remove all plant residues, twine, clips, mulch, etc. and maintain the house free of all vegetation, including weeds, for several weeks or months in-between tomato crops. Use of disease resistant varieties and rootstocks is also desirable.

In-Ground Culture

A greenhouse may be placed over high-quality field soil, but be sure to avoid soil compaction that can occur during the construction of the greenhouse. Even if the topsoil is worked up after heavy traffic, plants may suffer once roots reach the compacted subsoil. On compacted soils or poor fertility sites, it may be advisable to make raised beds.

Field soil in a greenhouse is usually initially amended with a large volume of organic matter such as well-made compost before growing greenhouse tomatoes. If uncomposted manure is used it should be applied at least 4 months prior to harvest to avoid contamination from human pathogens such as *E. coli*. Use of chicken manure in a greenhouse can generate excess ammonia that will damage plants.

Annual soil testing is critical to optimizing soil fertility for good productivity. Greenhouse soils amended with compost or manure may still require additional fertilization or liming for good plant and root growth. Often, additional N and K are needed annually but P levels may be excessive, especially after many years of compost application. Beds should be deeply tilled each year since nutrient salts tend to accumulate in the top 1-2 inches of soil. The soil should be tested for soluble salts (electrical conductivity) because rain does not leach salts from the greenhouse. If salt levels are excessive, the soil should be intensively irrigated, or the plastic covering should be removed over winter, to leach salts down into the soil profile. If leaching is necessary, it should be done well before planting. This allows time to retest the soil and apply appropriate nutrients since leaching often reduces nutrient levels. Avoid fertilizers with a high salt index (like potassium chloride) and those high in ammonium forms of N. Peat moss can be used to maintain organic matter and dilute high salt levels without adding additional nutrients or salts. High salt levels can also be diluted by mixing in low fertility field soil.

If a tunnel/greenhouse soil has been heavily amended with compost or manure, the use of the saturated media extract (SME) potting soil test as well as a regular field soil test (modified Morgan's extract) is recommended, in order to measure water-soluble as well as reserve nutrient levels. The

SME also tests for available nitrogen (as nitrate and ammonium) as well as salt levels. The combination of these two tests is offered as the “long-term high tunnel test” by the University of Maine Agricultural Testing Lab.

Fertilization should be based on soil test results and yield goals. Yields may vary from about 1 to 5 lbs/sq ft, depending on the duration of the crop, cultivar, and crop management.

Container Culture

This system typically employs ‘grow bags’ that contain artificial soil mix and allow for adequate drainage. Such mixes are similar to potting soils, comprised of peat, vermiculite and/or perlite, lime, fertilizers and wetting agents. There are many brands and formulations available. Be sure to select one that has a proven track record. These mixtures need to be supplied with additional nutrients after plants are well established to sustain crop growth. Soluble fertilizers can be injected into the irrigation water and adjusted to meet the needs of the plants. N-P-K should be supplied in a ratio of 1:1:1.25 until the fourth flower cluster, then the ratio is adjusted to 1.25:1:3 to increase the proportion of N and K. The level of N in solution is usually maintained at around 100 ppm during early growth stages, and gradually increased to 200 ppm by the time the plants are about 3’ high. A popular program is to use calcium nitrate plus a 7-11-27 or similar liquid fertilizer. These two materials are mixed with water to make separate stock solutions. These should be injected separately, but at the same time with 2 injectors. Follow directions on the 7-11-27 fertilizer label.

Leaf analysis. With both in-ground and container culture, leaf tissue (foliar) analysis is valuable for determining the nutritional status of tomato plants and the adequacy of a greenhouse fertility program. For accurate results, submit 15-20 recently matured whole leaves: these should be the 3rd or 4th leaf from the growing point, the first one to be at a 90-degree angle to the stem. Test early in the growing season so fertility adjustments can be made in a timely fashion.

Irrigation

A steady, sufficient supply of water is essential to good tomato production. Irregular or insufficient watering can result in blossom-end rot and fruit cracking. Some form of drip irrigation is recommended. Sufficient lines should be in place to completely wet the area that roots are expected to explore. In many tunnels this requires 3 or 4 drip lines per bed. An insufficient number of drip lines will leave areas of soil dry, therefore limiting root growth and nutrient uptake.

In-ground growing systems can utilize sensors places at several locations and depths to monitor soil moisture, although many growers simply feel the soil or growing medium to assess its water content. Once tomato plants are well grown, they utilize large quantities of water. Irrigation may then be needed more than once a day to maintain a consistent moisture supply. In order to minimize the development of foliar diseases, it is critical to avoid wetting the leaves of the plants when watering. Otherwise, an important benefit of greenhouse production will be lost.

N APPLICATION RATE BASED ON YIELD GOAL						
	Yield Goal (lb/Acre)	Yield (lb/ft ²)	Yield lb/stem (4 ft ²)	Approx. plant height	N need lb/acre @ 90% recovery	Total N need lb/1,000 ft ²
Tunnel - Low Yield	40,000	1	4	8'	100	2.3
Tunnel - Medium Yield	80,000	2	8	12'	200	4.6
Tunnel - Good Yield	120,000	3	12	16'	300	6.9
Tunnel - High Yield	160,000	4	16	20'	400	9.2

P₂O₅ application rate based on modified Morgan’s soil test result and yield goal								
	Low (<40 lb/A = <20 ppm)		Medium (40-80 lb/A = 20-40 ppm)		High/optimum (80-160 lb/A = 40-80 ppm)		Excessive (> 160 lb/A = > 80 ppm)	
	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²
Low Yield Goal	180	4.1	120	2.8	60	1.4	0	0
Medium Yield Goal	240	5.5	160	3.7	80	1.8	0	0
Good Yield Goal	300	6.9	200	4.6	100	2.3	0	0
High Yield Goal	360	8.3	140	5.5	120	2.8	0	0

K₂O application rate based on modified Morgan’s soil test result and yield goals								
	Low (<400 lb/A = <200 ppm K)		Medium (400-800 lb/A = 200-400 ppm K)		High/optimum (800-1200 lb/A = 400-600 ppm K)		Excessive (>1200 lb/A = >600 ppm K)	
	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²	lb/acre	lb/1000 ft ²
Low Yield Goal	300	6.9	200	4.6	100	2.2	0	0
Medium Yield Goal	450	10.3	300	6.9	150	3.4	0	0
Good Yield Goal	600	13.8	400	9.2	200	4.6	0	0
High Yield Goal	750	17.2	600	13.8	300	6.9	0	0

Transplants

Healthy transplants are key to a healthy crop. If starting your own plants, provide optimal conditions (light, heat, nutrients, water) to produce strong, stocky plants. Scout seedlings often for pests, and use sticky cards, indicator plants and other tools to monitor for infestations. If purchasing plants, inspect them carefully to be sure that they are not infected with disease, such as powdery mildew, or harbor insect pests, such as thrips. Close examination with a hand lens is essential. A period of quarantine and observation in a single area is advisable before setting plants out into tunnel(s).

Transplants with large root systems tend to take off faster, yield earlier, and cope with environmental stresses better than those with smaller roots. Thus, small pots, at least 2.5 inches in diameter, are preferable to cell trays for the last weeks of transplant production. The optimum germination temperature for tomato seed is 75°F, and the optimum temperature range for growth of the transplant is 60-70°F. Seeds should be sown approximately 5-7 weeks before transplanting.

Excessive watering, nitrogen, temperature or low light will cause excessive “leggy” growth. A good tomato transplant should be stocky. Tomato transplants can be conditioned or “hardened off” starting about 10 days before transplanting by taking plants from the starter greenhouse and exposing them to outside temperatures (over 50°F) and wind for a few hours each day. Tomatoes can be transplanted into tunnel or greenhouse soil once soil temperatures reach 60°F at a 2-inch depth. For early production, row covers, raised beds, plastic mulch and (back-up) heat should be considered to promote growth and/or reduce risk of chilling injury.

Each leader on tomato plants should occupy about 3.5-6 sq ft of area. Using a high planting density can lead to increased yields, but will also reduce air movement, which can promote foliar disease, especially in susceptible cultivars and in tunnels with inadequate ventilation.

Grafting

Grafting is a way to manage root diseases and increase plant vigor. In-ground growers, in particular, may benefit from grafting because growing tomatoes in soil rather than in artificial media often leads to problems with root disease. Any tomato variety can be used as the scion (top) but far fewer varieties are available for rootstocks, and these vary in the degree of vigor they confer on the plant.

Two common grafting techniques are top grafting and side grafting. With top grafting, the scion is completely cut off from its roots and placed on top of the rootstock stem. Side grafting involves making a partial cut into the stem of the scion plant and then inserting the cut-off stem of the rootstock into that cut. The seedling is then allowed to retain both sets of roots until the graft with the new rootstock heals, after which the original root is cut from the plant. Top grafting relies on a tiny plastic tube or sleeve to hold the scion and rootstock together until the graft heals. Top grafting is quicker and a bit less complicated to do than side grafting because it requires only a single complete cut through both the root and the shoot portions of the graft. This technique can be used on very small seedlings.

Side grafting takes a little longer but is preferred by some growers because it is a bit more forgiving. If greenhouse

conditions for graft healing are less than ideal, the grafted seedling still has its original set of roots to help during the transition. Side grafting can also be done with seedlings that have become larger than is ideal for top grafting. A small clip, much like an office binder clip, is used to hold side grafted plants together until they heal.

Some growers produce sequential planting of seedlings over several days to assure that they have the right selection of plant sizes to choose from for grafting. The scion and rootstock stem diameters must be similar, and grafting is most effective on very small plants. The ideal size is when the stems are about 2 mm in diameter for top grafting and 2-3 mm for side grafting. After grafting, keep the plants in a shaded area at about 80-85°F and 95% relative humidity while the grafts heal. They should be misted enough to maintain relative humidity, but not so much that the leaves are wet all the time. Healing takes about 4-5 days for top grafts and 6-7 days for side grafts. Placing high plastic domes over trays of top-grafted plants appears to enhance success. For a couple of days before setting the grafted plants out, gradually increase their exposure to direct light by pulling them out from under cover for a few hours early or late in the day. If using plastic domes, prop them open during this time to increase air flow.

Because grafted plants are more vigorous, they will produce a lot of vegetative growth at the expense of reproductive growth. In other words: too much foliage and not enough fruit. Vigor can be reduced by allowing the first sucker on the scion to grow into a second fruiting leader. Leaf removal also reduces vigor. Only 10-12 fully expanded leaves are needed to capture sunlight to feed a grafted tomato plant in the Northeast. Take care to leave sufficient leaf cover over the fruit clusters to avoid sun scald. Cut or snap off suckers cleanly; do not leave stubs on the stem that may promote disease.

Mulching

For early tomato production, black, clear or IRT (infrared transmitting) mulch can be applied to increase soil temperatures, reduce weed emergence and soil evaporation. For maximum effectiveness, black plastic mulch should have good contact between the mulch and the surface of the bed for effective transfer of heat. Embossed plastic mulch will fit tightly over the bed. Clear plastic will increase soil temperatures significantly more than black plastic, but weeds will emerge under the clear film. White plastic (white-on-black or white) will significantly lower soil temperatures and can be used for late summer or fall high tunnel tomato production. Organic mulches such as straw, hay or compost can be used for high tunnel tomatoes. Organic mulches create a favorable environment for many beneficial insects while increasing organic matter. However, some organic mulches (straw or hay) can significantly lower soil temperature and thus would not be effective for warming the soil in the spring. Compost can increase soil temperatures, but not as effectively as black plastic mulch. Organic mulches can be applied when the soil temperatures have increased.

Pruning

Greenhouse tomatoes are normally pruned to a single stem and the plant is supported by nylon twine tied loosely at the base of each plant row and secured to a wire at least 8' above

the bed. The twine is clipped to or spiraled around the stem as it grows. All suckers are removed, ideally when they are only 2-3" long. The plant may be topped when it reaches the supporting wire or, to extend the production season, the plant can be looped over the top wire and allowed to grow 3'-4' down the other side before topping. This, however, may lead to a dense canopy with poor air circulation, setting up conditions for disease. Another way to prolong the season is to untie the support twine from the overhead wire, lower the plants 2'-3', lay the stems down on the ground, move and re-tie the support twine. Remove the lower foliage after harvest of the lower clusters to improve air circulation and allow for lowering the plants; the lower leaves contribute little to the plant at this stage. Note: Frequent handling of plants is a primary means of spreading Tobacco Mosaic Virus (TMV) and tomato canker. Wash hands frequently and don't handle tobacco products.

Pollination

Tomato plants do not need a specific day length in order to flower. The flowers are self-pollinated but require vibration by shaking, wind, or insects to assure good pollination. The optimum temperatures for pollination are 68-75°F (night) and 60-90°F (day). Air temperature below 55°F or over 95°F can cause flowers to drop from the plant. High humidity can also adversely affect pollination. Daily shaking of flowers, especially during damp and cloudy weather when pollen does not release well, can be achieved with a hand-held mechanical vibrator with a probe that just touches the flower cluster. Some growers shake the plant support wires daily, but this may not be adequate for lower clusters. A backpack blower will also provide good pollination and reduce labor costs; electric units are preferable to internal combustion engines which release ethylene and carbon monoxide; both can damage tomatoes and the latter is harmful to humans. Commercially available hives of bumble bees are widely used to assure effective pollination of greenhouse tomatoes. A well-ventilated high tunnel in a steadily breezy location is usually adequate, once outside temperatures are warm enough to open the tunnel during the day.

Temperature

High-quality thermostats should be used to manage greenhouse temperature. Daytime temperature of 75°-80°F is ideal; use ventilation and/or shading to keep temperatures below 85°F. Maintain night temperatures of 62°-65°F after sunny days and 60°-62°F after cloudy days. Rough fruit develops with temperatures lower than 60°F during flower initiation which begins several weeks before flowers appear (seedling stage). For passively ventilated gothic-style high tunnels, consider installing a ridge vent or gable vents in the top of end walls to promote ventilation and cooling. Roll-up sides alone are often inadequate for good ventilation, especially in locations with little wind, and once the tomato canopy is dense. If mechanically ventilating, fans and louvers should be properly sized to move air through and out of the greenhouse or tunnel even when the tomato canopy is fully mature. Root-zone heating can be beneficial to early-season production, as it is difficult to warm the soil from above, whether the air is heated passively or with a heating system.

Humidity

Effective ventilation is also needed to manage humidity. Keeping relative humidity below 90% will help avoid foliar

diseases and optimize pollination. Excess humidity also restricts transpiration and water flow through the plant which restricts calcium uptake and can lead to blossom end rot and/or fruit cracking. Oedema is caused by excessive water uptake when soils are warm and moist but humidity is high, so leaf stomates are closed and leaf cells 'burst'. Cool air can exacerbate this condition.

On cool nights, a combination of ventilation and heating is needed to reduce humidity. Ventilation exchanges moist air with drier air from outdoors while heating brings outdoor air up to optimum growing temperature and increases the capacity of the air to hold moisture, avoiding condensation. In greenhouses with vents, turn on the heat and crack the vents open so warmed humid air can escape and be replaced with drier outside air. In houses with fans, they should be operated for a few minutes to cool the house down from day to evening temperatures. During the night, a clock could be set to activate the exhaust fans for 20-30 seconds, 2-3 times per hour. A relay is needed to lock out the heater until the fans shut off so that both the fans and heating system do not operate at the same time. Otherwise, flue gases will be drawn into the greenhouse. The venting and heating cycle should be done several times after the sun goes down and at sunrise. For some greenhouses it may take a few minutes per air exchange; with passive ventilation, it may take 30 minutes. Heating and venting is effective even if it's cool and raining outside. The relative humidity of air at 50°F/100% RH can be cut in half (50%RH) when it is heated to 70°F.

Horizontal air flow (HAF) fans keep the air moving in the greenhouse, helping to mix it, thus minimize temperature and CO₂ differentials. This can reduce condensation in colder areas. Air that is moving is continually mixed along the surface of leaves is less likely to cool below the dew point so does not condense on plant surfaces. In a 30' x 100' greenhouse, four fans each with at least 1600 cfm output are needed to keep the air mass moving. Fans should be mounted above the canopy, about ¼ of the width of the greenhouse from the sidewall. On each side, the first fan should be located 10'-15' from the endwall to catch air coming around the corner, the next fan should be located 30'-50' away, but no closer than 50' from the endwall, to keep the air moving.

For more information on environmental controls, see High Tunnels, page 33.

Managing Plant Growth

Greenhouse tomatoes tend to cycle between being overly vegetative (too much plant growth and too little fruiting) early in the season and being overly generative (too little plant growth and excessive fruit load) later in the season. The greenhouse environment can be manipulated to try to balance plant growth. A well-balanced plant has a stem about 3/8" (1 cm) thick at a point 6 inches below the growing point. It has dark green leaves, and large, closely spaced, readily-setting flower clusters.

Low light and low transpiration tend to promote vegetative growth. In an overly vegetative plant, stems are thicker and fruit set is low. Flowers appear far down from the top of the plants, open slowly and incompletely and are pale yellow. The uppermost leaves are flat, soft, long, light-colored, and may have a somewhat mottled appearance. The cluster stem is thin and long. Fruit will be slow to develop, few in number, and may be misshapen.

To steer the plant to a more generative growth pattern the difference between day and night temperatures can be increased by up to 9°F and temperatures reduced more quickly in the early evening when going from day to night set-points. Greenhouse temperatures should be raised, the relative humidity should be lowered and ventilation should be increased. Increasing transpiration reduces turgor pressure and inclines the plant to generative, rather than vegetative growth. CO₂ enrichment also encourages generative growth.

In an overly generative plant, stems are thinner (indicating lack of carbohydrates), growth is slow, and trusses are short and horizontal. Dark yellow flowers appear immediately below the top of the plant and open quickly. Although fruit are large, well-shaped, and develop rapidly in an overly generative plant, over the long term, yields will be reduced because growth is reduced at the top. Leaves at the very top of a too generative plant develop slowly resulting in short, dark, strong leaves, which may be curled under.

To correct an overly generative plant, day temperatures are lowered to re-direct assimilate from the already-set fruit to the top of the plant and the developing trusses, but do not lower night temperatures as this will slow down fruit ripening, prolonging the problem of too much assimilate going to the older fruit. Reducing transpiration by raising relative humidity or reducing ventilation also stimulates vegetative growth.

Ethylene Injury

Combustion gases, which contain ethylene, can enter the greenhouse via faulty heat equipment. Even at very low levels, ethylene can make tomato leaves bend downward or become twisted and contorted (epinasty), and if exposure is ongoing, stems may thicken, branching may increase, and flower buds may abort or develop into malformed fruit. To prevent ethylene injury, hire professionals to perform proper heating system maintenance before the start of the heating season. High ammonium can stimulate plants to produce ethylene. Avoid fertilizers high in ammonium and be sure composts are finished. Composts should always be tested before using in the greenhouse. If growing in containers, be sure they have adequate bottom drainage. Saturated, highly organic media in the bottom of containers can spontaneously generate ethylene in rare cases.

Harvest and Storage

Greenhouse tomatoes are usually picked at the turning stage or later and packed by uniform ripeness and size in single or double layer cartons. Fruits are sensitive to compression injury so pack and display accordingly. For best flavor greenhouse fruits should be fully ripe when harvested, if your markets may allow, but cracking is a risk if fruit are left on the plant too long. Ripe fruit can be held for a couple of days at 45-50°F but flavor and aroma may be reduced compared to storage at room temperature.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical

Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

PESTICIDE USE IN GREENHOUSES AND HIGH TUNNELS:

Pesticides can be used on high tunnel and greenhouse crops if: 1) the crop and pest/disease is on the label, AND the products specifically says it can be used in the greenhouse; OR 2) the crop and pest/disease is on the label, AND the product is 'silent' about use in the greenhouse in the greenhouse. Products that specifically prohibit greenhouse use cannot be used in greenhouses or high tunnels regardless of the crops or pests/diseases listed on the label.

Management practices that will reduce disease in greenhouses and high tunnels are: the use of resistant varieties, sanitation, fungicides and cultural practices that keep the humidity below 90%.

See also: Table 19: Fungicides and Bactericides Labeled for Vegetable Bedding Plants, page 54.

■ Bacterial Canker (*Clavibacter michiganensis* pv. *michiganensis*)

Initial symptoms are often a wilting and/or scorching of half of a leaf or one side of a plant. Necrotic leaf lesions up to 1/4" in diameter may appear on the upper leaf surface of mature leaves. Slightly raised white spots called "birds-eye spots" about 1/16" in diameter can appear on the fruit, usually when the green fruit is 1/2" to 2" in diameter. When these symptoms occur, remove the entire plant, including roots from the greenhouse. Wash hands with soap and water before handling healthy plants. There are few effective bactericides to control this disease. If extensive bacterial canker occurs in the greenhouse, steaming of the soil is advised. Pruning, harvesting and handling, especially when plants are wet, spreads the bacterium down the row. See discussion of bacterial canker on Tomato (Outdoor).

***Bacillus subtilis* strain QST 713 (Serenade ASO^{OG}):** 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. See label for tank mix rates and restrictions for greenhouse use.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 0.75 to 1.8 lb/A; PHI 0d, REI 24h, Group M1.

***Reynoutria sachalinensis* extract (Regalia):** 0.5-1.0% v/v solution; PHI 0d, REI 4h, Group P5. Plant activator. Apply preventatively beginning when plants are young.

■ Gray Mold/Botrytis Blight (*Botrytis cinerea*)

White ring spots or "ghost spots" may appear on green fruit due to an earlier infection. Control over the environment is very important in controlling this disease. Keep humidity below 80% by heating and ventilating, especially at night. Avoid wetting the foliage during times when drying is slow. Practice strict sanitation, removing senescent tissues and infected crop debris. Pruning of lower leaves to clean-cut stubs aids in disease prevention by improving air circulation through the crop. Fungicide rotations and combinations are important because strains resistant to benlates, dichloran, captan, and iprodione have been reported.

Bacillus amyloliquefaciens strain D747 (DoubleNickel LC^{OG}): 0.25 to 3.0 lb/A; PHI 0d, 4 hr, Group 44.

Bacillus subtilis strain QST 713 (Cease^{OG}): 3.0 to 6.0 qt/A; PHI 0d, 4 hr, Group 44.

copper soap (Camelot O^{OG}): 0.5 to 2.0 gal/30 to 100 gal water; PHI 0d, REI 4h, Group M1.

copper sulfate basic (Cuprofix Ultra^{OG}): rates vary with products; REI 48h, Group M1. See labels.

copper sulfate pentahydrate (Phyton 35): 20.0 to 40.0 fl oz/100 gal water - fresh market tomatoes; PHI 3d, REI 24h, Group M1. Do not exceed 80lb metallic copper annually. See label for restrictions.

cyprodinil plus fludioxonil (Switch 62.5 WG): 11.0 to 14.0 oz/A; PHI 10d, REI 12h, Groups 9 & 12.

fenhexamid (Decree 50 WDG): 1.0 to 1.5 lb/A; PHI 1d, REI 12h, Group 17. Treated greenhouse tomatoes cannot be used for processing.

fludioxonil (Emblem): 5.5 to 7.0 oz/A; PHI 0d, REI 12h, Group 12. Alternate with a different mode of action (FRAC group) after 2 applications of Emblem.

fluopyram plus pyrimethanil (Luna Tranquility): 11.2 fl oz/A; PHI 0d, REI 12h, Groups 7 & 9. See label for specific instructions for greenhouse use.

penthiopyrad (Fontelis): 0.5 to 0.75 fl oz/ gal of spray; PHI 0d, REI 12, Group 7.

polyoxin D (Affirm WDG): 6.2 oz/A; PHI 0d, REI 4h, Group 19.

potassium bicarbonate (MilStop^{OG}): 1.25 to 5.0 lb/100 gal water; PHI 0d, REI 1h, Group NC. Use solution within 12 hours of preparation. See label for small volume application rates.

pyrimethanil (Scala SC): 7.0 fl oz/A; PHI 1d, REI 12h, Group 9. Use only in a tank mix with another effective fungicide recommended for Botrytis. Apply Scala SC only in well ventilated plastic tunnel houses or glass houses. Ventilate for at least 2 hours after application.

Reynoutria sachalinensis extract (Regalia^{OG}): 0.5 to 1.0% v/v solution; PHI 0d, REI 4h, Group P5. Plant activator. Apply preventatively beginning when plants are young.

■ Late Blight (*Phytophthora infestans*)

Protectant fungicides are a key tool for management; however, many strains of *P. infestans* have become resistant to mefenoxam. When resistant strains are present, early blight fungicides will give as much protection against late blight as mefenoxam combinations. Avoid the use of overhead irrigation. Promptly incorporate old tomato crops after harvest in high tunnels; in the greenhouse remove all debris and clean greenhouse thoroughly after harvest. Eliminate cull piles and volunteer plants of both tomato and potato. Some resistant cultivars are available.

Bacillus pumilis Strain QST2808 (Sonata^{OG}): 2.0 to 4.0 qt/100 gal of spray mix; PHI 0d, REI 3h, Group NC. For disease suppression only (in greenhouse use).

Bacillus subtilis Strain QST 713 (Cease^{OG}): 3.0 to 6.0 qt/A; PHI 0d, REI 4h, Group 44.

copper hydroxide (Kocide 3000): 0.5 to 1.5 Tbsp/1000 sq ft (1lb/A); PHI 0d, REI 24h, Group M1. Do not apply in a spray solution having a pH less than 6.5.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 0.75 to 1.8 lb/A; PHI 0d, REI 24h, Group M1.

copper soap (Camelot O^{OG}): 0.5 to 2.0 gal/30 to 100 gal water; PHI 1d, REI 4h, Group M1.

cyazofamid (Ranman 400SC): 2.1 to 2.75 fl oz/A; PHI 0d, REI 12, Group 21. See label for surfactant recommendations. Alternate applications with fungicides that have a different mode of action.

mancozeb (Dithane M45): 1.5 to 2.0 lb/A; PHI 5d, REI 24h, Group M3.

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48, Groups M3 & 22.

mandipropamid (Micora): 5.5 to 8.0 fl oz/A; PHI 1d, REI 4h, Group 40. For tomato late blight only. Do not make more than 2 consecutive applications. See label for surfactant recommendation.

mandipropamid + difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12, Groups 3 & 40.

phosphorous acid (K-Phite 7LP): 3.0 to 5.0 qt/A via ground or aerial application; PHI 0d, REI 4h, Group 33.

polyoxin D (Affirm WDG): 6.2 fl oz./A; PHI 0d, REI 4h, Group 19.

■ Leaf Mold (*Fulvia fulva*)

This disease occurs in both soil or hydroponic production and is most important in poorly ventilated plastic greenhouses. The pathogen produces large numbers of conidia on infected tissue; the disease can spread rapidly throughout a greenhouse by air currents, water, insects, and workers. Start with certified disease-free seed. Use resistant cultivars. Improve air circulation by adequate row/plant spacings and removal of lower leaves. Avoid the formation of water droplets on leaves by watering in the morning. Reduce relative humidity by a combination of heating and venting, especially at night. Avoid excessive nitrogen fertilization. Remove diseased leaves, place in plastic bag, and destroy. At the end of crop cycle, remove and destroy all plant residue and disinfest the entire greenhouse.

copper hydroxide (Kocide 3000): 0.5 to 1.5 Tbsp/1000 sq ft (1 lb/A); PHI 0d, REI 24h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

copper oxychloride plus copper hydroxide (Badge X2^{OG}): 0.75 to 1.8 lb/A; PHI 0d, REI 24h, Group M1.

copper soap (Camelot O^{OG}): 0.5 to 2.0 gal/30 to 100 gal water; PHI 1d, REI 4h, Group M1.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27.

mancozeb (Dithane M45): 1.5 to 2.0 lb/A; PHI 5d, REI 24h, Group M3.

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48h, Groups M3 & 22.

mandipropamid plus difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12h, Groups 3 & 40.

polyoxin D (OSO): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

■ Powdery Mildew (*Oidium neolycopersici*)

Powdery mildew of tomato is emerging as an important disease of greenhouse crops. This pathogen is favored by low light and cool temperatures. In contrast to other fungal plant pathogens, it does not require free water to germinate and cause disease. DeRuiter's Seeds has recently released the cultivar Grace which has resistance to powdery mildew.

***Bacillus pumilis* strain QST2808 (Sonata^{OG}):** 2.0 to 4.0 qt/100 gal of spray mix; PHI 0d, REI 3h, Group NC. For disease suppression only (in greenhouse use).

***Bacillus subtilis* strain QST 713 (Cease^{OG}):** 3 to 6 qt/A; PHI 0d, REI 4 hr, Group 44.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 12. Do not apply to small tomatoes such as cherry or grape in the greenhouse.

fludioxonil (Emblem): 5.5 to 7.0 oz/A. PHI 0d, REI 12h, Group 12. Alternate with a different mode of action (FRAC group) after 2 applications of Emblem.

fluopyram plus pyrimethanil (Luna Tranquility): 11.2 fl oz/A; PHI 0d, REI 12h, Groups 7 & 9. See label for specific instructions for greenhouse use.

paraffinic oil (JMS Stylet-Oil): 3.0 to 6.0 qt/100 gal water; PHI 0d, REI 4h, Group NC. Spray for thorough coverage of upper leaf surface.

penthiopyrad (Fontelis): 0.5 to 0.75 fl oz/ gal of spray; PHI 0d, REI 12, Group 7.

phosphorous acid (K-Phite 7LP): 3.0 to 5.0 qt/A; via ground or aerial application PHI 0d, REI 4h, Group 33.

polyoxin D (Affirm): 6.2 fl oz/A; PHI 0d, REI 4h, Group 19.

potassium bicarbonate (MilStop^{OG}): 2.5 to 5.0 lb/100 gal water; PHI 0d, REI 1h, Group NC. Use solution within 12 hours of preparation.

potassium salts of fatty acids (M-Pede^{OG}): 1.0% to 2.0% solution in tank mix; 1.5 to 2.0% v/v solution for stand alone use; PHI 0d, REI 12h, Group NC. See label for precautions.

mandipropamid + difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12, Groups 3 & 40.

sulfur (Microthiol Dispers^{OG}): 5.0 to 20 lb/A; PHI 0d, REI 24h, Group M2. Do not use within 2 weeks of an oil spray treatment. Crops grown in greenhouses may be much more sensitive to sulfur injury. Do not use if temperature will exceed 90°F within 3 days following spraying.

triflumizole (Trionic 4 SC): 2 to 4 fl oz/100 gal.; PHI 1d, REI 12h, Group 3. Apply only as foliar spray. See label for surfactant recommendation.

■ Soil-borne Diseases

The fungi *Rhizoctonia*, *Pythium*, *Phytophthora*, *Colletotrichum*, *Verticillium*, *Sclerotinia*, and *Fusarium*, the bacterium that causes tomato canker, and root knot nematodes may become

established in greenhouse soils or survive in tomato roots left from a previous crop. White rot (*Sclerotinia*) on stems occurs erratically during moist, cool periods in the spring. Distribution of diseased plants in a greenhouse is random. Plants of all ages are susceptible. The pathogen produces hardened black fungal survival structures called sclerotia that can survive several years in the soil. Cut the plant off at the base and remove from the greenhouse. Depending on which pathogen is present, rotation or the use of resistant varieties in addition to the use of grafted plants with vigorous rootstocks may be viable alternatives. Otherwise, steam or chemical treatment of the soil is necessary. It should be considered, however, that treatment of soil may not entirely eliminate the pathogens and, in the case of *Pythium*, *Rhizoctonia*, and *Fusarium*, the pathogens may rapidly recolonize the soil. There is no effective chemical treatment for the wilt and decline diseases caused by *Verticillium* and *Fusarium*. The most effective management techniques are resistant cultivars and sanitation, including soil pasteurization. (NOTE: the current Bayer label for *Coniothyrium minitans* (Contans) does not include tomato).

***Bacillus subtilis* v. *amyloliquefaciens* FZB24 (Taegro 2.0^{OG}):** 2.6 to 5.2 oz/A; REI 24h, Group NC. In greenhouse production, apply Taegro to newly sown transplants.

***Bacillus subtilis* strain QST 713 (Serenade ASO^{OG}):** 2.0 to 4.0 qt/A; PHI 0d, REI 4h, Group 44. See label for tank mix rates and restrictions for greenhouse use.

cyazofamid (Ranman): *Pythium* ONLY. 3 fl oz/100 gal water; PHI 0d, REI 12h, Group 21. Use as a soil drench. For tomato transplants only.

***Gliocladium catenulatum* strain J1446 (P-Vent^{OG}):** See label for rates and application instructions; REI 4h, Group NC.

mancozeb (Dithane M45): 8 oz/100 lb seed; REI 24h, Group M3.

PCNB (Terraclor 400): 6.0 to 12.0 fl oz/100 gal water (800 sq ft); REI 12h, Group 14. Use as soil drench in greenhouse for seedlings grown in containers or beds prior to transplant.

phosphorous acid (K-Phite 7LP): see label for rates and application methods; PHI 0d, REI 4h, Group 33.

propamocarb HCl (Previcur Flex): *Pythium* and *Phytophthora* species ONLY. See label for rates; REI 12h, Group 28. Prevent intense sunlight after application by applying Previcur Flex in the evening. Do not apply to dry rockwool or other dry growing media without first pre-wetting with water.

***Streptomyces griseoviridis* (Mycostop^{OG}):** 0.08 oz/lb seed for seed treatment. 1 to 2 g/cubic yd for soil incorporation. 1.0 to 2.0 g/100 ft² for soil Drench; REI 4h, Group NC. See label for soil application methods and rates.

***Streptomyces lydicus* (Actinovate^{OG}):** 3.0 to 12.0 oz/A applied as soil drench; REI 1h, Group NC.

***Trichoderma asperellum* plus *T. gamsii* (Bio-tam 2.0^{OG}):** See label for use and rates; REI 1h, Group NC.

***Trichoderma* species (RootShieldOG, Rootshield Plus^{OG}):** See labels for specific instructions and rates; REI 0h, Group N/A.

■ Viruses

See Tomato (Outdoor) for a discussion on viruses.

INSECT CONTROL

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

Note: For best results with aerosols, apply when air temperature in the greenhouse is 70°F to 80°F. Keep vents closed and fans off during treatment. Ventilate greenhouse before entering DO NOT perform this operation alone.

PESTICIDE USE IN GREENHOUSES AND HIGH TUNNELS:

Pesticides can be used on high tunnel and greenhouse crops if: 1) the crop and pest/disease is on the label, AND the products specifically says it can be used in the greenhouse; OR 2) the crop and pest/disease is on the label, AND the product is 'silent' about use in the greenhouse in the greenhouse. Products that specifically prohibit greenhouse use cannot be used in greenhouses or high tunnels regardless of the crops or pests/diseases listed on the label.

■ Aphids, Twospotted Spider Mite, Thrips, Fungus Gnats

Scouting and preventative, timely releases of biological controls can be effective in managing aphids, thrips, spider mites and fungus gnats in greenhouse tomato. See potato aphid in the insect control section of Potato, green peach aphid in the insect control section of Pepper, spider mites in Tomato, Outdoor. Refer also to the Transplant Insect and Mite Management section for more information about greenhouse pests, including Table 18, page 51, for scouting and biological control guidelines and Table 20, page 63, about insecticides labeled for vegetable transplants in the greenhouse. Note that some of the products listed in these tables are only labeled for transplants, not crops to be sold such as greenhouse tomatoes.

Please refer to the following guides for more information on biology and monitoring of these pests in greenhouse crops and how to integrate cultural practices, biological control and pesticides: The New England Greenhouse Floriculture Guide and the Penn State manual Greenhouse IPM with an Emphasis on Biocontrols.

abamectin (Agri-Mek SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. For two-spotted spider mite and thrips only. Must be mixed with a non-ionic activator type wetting, spreading, and/or penetrating spray adjuvant. Do not use binder or sticker type adjuvant.

acequinocyl (Kanemite 15SC): 31 oz/A; PHI 1d, REI 12h, Bee: L, Group 20B. For two-spotted spider mite only. Do

not use less than 100 gal water/A. Use of an adjuvant or surfactant is prohibited.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

Bacillus thuringiensis subsp. israelensis (Gnatrol WDG^{OG}): 3.2 to 26 oz/100 gal; REI 4h, Bee: L, Group 11. Use higher rate for heavy infestation. Apply as soil drench to flats to control larvae. Fungus gnat larvae only.

Beauveria bassiana (Mycotrol ESO): .0.5 to 1 qt/100 gal water; PHI 0d, REI 4h, Bee: L, Group 22. For aphids and thrips. Use high rate for thrips. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control. Repeat applications may be needed.

bifenazate (Floramite SC): 0.25 to 0.5 tsp/gal or 4 to 8 oz/100 gal water (apply 1 to 4 qt mix/100 sq ft or 100 to 400 gal/A); PHI 3d, REI 12h, Bee: L, Group 25. Mites on greenhouse tomatoes only. Apply when mites first appear.

Burkholderia spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}): 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

chlorfenapyr (Pylon Miticide-Insecticide): 6.5 to 13 oz/A for mites and 9.8 to 13 oz/A for thrips; PHI 0d, REI 12h, Bee: M, Group 13. Mites and thrips only.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28. Suppression of thrips only.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. Do not apply to varieties with fruit that is less than 2" such as cherry or grape tomatoes.

imidacloprid (Admire Pro): 0.6 oz/1,000 plants; PHI 0d, REI 12h, Bee: H, Group 4. Aphids only. Use on mature plants only. Apply in a minimum of 16 gal water. Do not apply to plants grown in non-soil media.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. Not for fungus gnats. Repeat application every 2 to 3 days until pest is under control. For enhanced and residual control apply with companion labeled aphicide.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L. Thrips and mites only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. Not for fungus gnats.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; For backpack sprayers: 0.25 to 0.50 oz/gal (applied at 3000 diluted gal/sq ft); PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Distance IGR): 2 oz/100 gal as a surface drench to top 1" of soil media, 3 to 6 oz/100 gal as a heavy coarse spray to soil surface for fungus gnats and shore flies;

6 oz/100 gal for suppression of aphids; *PHI 1d, REI 12h, Bee: L, Group 7D*. Do not apply to tomato varieties less than 1" in diameter, such as cherry or grape tomatoes.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4C*. Aphids only. Do not apply until after petal fall. Do not treat seedling plants grown for transplant.

■ Hornworms, Fruitworms, Loopers, Armyworm

Hornworms are large green caterpillars with white stripes along the sides that may grow up to 4" long. Look for the large pellet-like fecal droppings on the plastic under the plants, defoliation of leaves with only bare stems remaining, or surface feeding scars on green fruit. Caterpillar infestations usually begin in July and may extend through September. Spot-treat infested areas of the greenhouse. Use selective insecticides to preserve natural enemies and avoid secondary pest outbreaks (i.e. aphids). See cabbage looper in the insect control section of Cabbage, and tomato fruitworm and tomato hornworm in the insect control section of Tomato (Outdoor) for more information on these pests. Several species of armyworm feed on tomato fruits. See pepper section for more on armyworm.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; *PHI 0d, REI 4h, Bee: L, Group un*. For young larvae.

***Bacillus thuringiensis* subsp. *aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11*. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis* subsp. *kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11*. Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M*.

chlorfenapyr (Pylon Miticide-Insecticide): 6.5 to 13 oz/A; *PHI 0d, REI 12h, Bee: M, Group 13*.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M*.

novaluron (Rimon 0.83EC): 9 to 12 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16B*.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A*.

■ Slugs

See Cabbage section for more information on slugs.

iron phosphate (Sluggo: Snail and Slug Bait^{OG}): 20 to 44 lbs. per acre or 0.5 to 1 lb per 1,000 square feet or 1/2 tsp/9" pot; *PHI 0d, REI 0h, Bee: L, Group 9B*. Apply to moist soil in evening; scatter on soil around plants, or in and around pots.

■ Spotted Wing Drosophila (*Drosophila suzukii*)

Spotted Wing Drosophila (SWD) is an invasive pest that first arrived and spread throughout New England in 2011. It is primarily a pest of fruit crops, where the ability to oviposit in sound fruit (especially blueberry, raspberry, cherry, and peach) makes it a more serious pest than native fruit flies. SWD is deterred from laying eggs in sound tomato fruit by the strength of the tomato skin. However, where there are cracks and other openings, eggs are laid and larvae build up in fruit, liquefying the fruit contents and leaving nothing but an empty skin. Thus the management of cracked fruit is key to preventing buildup of spotted wing populations in tomato and possible contamination of cracked tomato fruit and containers post-harvest. Infestation can occur in the field or in high tunnels and greenhouse tomatoes. Buildup in tomato can increase the risk to more susceptible crops on the farm.

Cultural practices are likely to be more effective than insecticides in reducing these risks. Avoid planting varieties that are prone to cracking. When possible, maintain steady soil moisture to avoid a surge in uptake of water by tomato plants, which increases cracking. Remove culls from the greenhouse. Minimize cracked fruit by harvesting before fruit is completely ripe—especially with cherry tomatoes which are prone to cracking. The same postharvest practices that you already use to minimize native fruit flies will also help with SWD. Keep packing areas clean and remove culls daily. Keep cherry tomatoes in shallow containers for easier sorting. Compost and cover culled, injured or cracked fruit. Store fruit at the coolest temperatures suitable for tomato to delay egg hatch, if eggs are present.

Follow Extension monitoring alerts to know when SWD is starting to build up in your area. Currently, there are no thresholds for use of insecticides to control SWD in tomato. Few insecticides are registered specifically for control of SWD on tomato. Consult Extension SWD materials for updates on efficacy of products labeled for tomato.

malathion (Malathion 57 EC): 2.5 pt/A or 1.5 to 2 pt/100 gal water; *PHI 1d, REI 12h, Bee: H, Group 1B*.

■ Variegated Cutworm (*Peridroma saucia*)

Variegated cutworms will feed on leaves, but will also chew shallow or deep holes in the fruit during mid- to late summer. Caterpillars are brownish-grey, with diamond-shaped marks along the back and light lines along the sides. They are up to 2" long. Scout fruit for damage during harvest. Spray tomatoes if 1% of the plants are infested with variegated cutworms. For best results, make application after dark. Thorough coverage of the foliage is needed for good control. Neem (azadirachtin) interrupts larval development and acts as a feeding deterrent. See Tomato (Outdoor) section for more information on variegated cutworm.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; *PHI 0d, REI 4h, Bee: L, Group un*. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake. For larvae only.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M*.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 1 to 3 lb/A; *PHI 0d, REI 4h, Bee: M*.

spinosad (Seduce^{OG}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; *PHI 1d, REI 4h, Bee: M, Group 5.* Spread bait on soil around plants.

■ **Whiteflies, Greenhouse (*Trialeurodes vaporariorum*) and Sweet Potato (*Bemisia tabaci*)**

The primary whitefly species in greenhouses are the greenhouse whitefly (*Trialeurodes vaporariorum*) and sweet potato whitefly *B*-biotype (*Bemisia tabaci*), which is also known as the silverleaf whitefly (*Bemisia argentifolii*). Greenhouse whitefly is more common on greenhouse tomatoes, but both species occur in greenhouses, and correct identification of which species is present is important in order to select effective biological controls. The host range of greenhouse whitefly includes many ornamentals and vegetables; among greenhouse-grown vegetables the most common hosts are tomato, eggplant and cucumber. In the field, bean, cucumber, cantaloupe, lettuce, squash, tomato and eggplant are good hosts, with cabbage, sweet potato, pepper and potato less suitable. Sweet potato whitefly also has a wide host range, with cucurbit and sweet potato crops favored as well as fruiting crops.

Greenhouse whitefly adults are more active at temperatures around 75°F. Adults are winged, white, and 1/16" (2.0 mm) long. Greenhouse whitefly adults hold their wings flat, parallel to the top of the body. Females lay more than 20 eggs in a small circle. Newly laid eggs are white and eventually turn gray. Young nymphs (crawlers) are white, have legs and antennae, and move short distances before locating suitable places to initiate feeding. More mature nymphs (third and fourth instars) are typically found on the lower leaves. Pupae do not feed, and have distinct visible red eyes. Greenhouse whitefly pupae may possess long waxy filaments encircling the outer edge, and are elevated in profile with vertical sides, resembling "cakes" on leaf surfaces.

Sweet potato whitefly *B*-biotype adults prefer temperatures >80°F. The adults are yellow and smaller than greenhouse whitefly. Their wings are tilted, and held roof-like over their bodies. Adult females live up to 6 weeks, and produce up to 200 eggs, which are randomly laid in small clusters on new plant growth. Newly laid eggs are white and then turn amber-brown. Young nymphs (crawlers) have legs and antennae and move short distances before locating suitable places to initiate feeding. More mature nymphs (third and fourth instars) are typically found on the lower leaves. Sweet potato whitefly *B*-biotype nymphs are yellow, oval and dome-shaped, and do not possess long waxy filaments.

Large populations of whiteflies cause leaves to turn yellow, appear dry, or fall off plants. Honeydew excreted by whiteflies encourages growth of black sooty mold, and also attracts ants that interfere with natural enemies of other pests.

Avoid overfertilizing crops as this increases their attractiveness to adult whiteflies. Whiteflies may be introduced into greenhouses on infested cuttings or plants arriving from outside sources. Carryover or stock plants may also be a source of whiteflies. Using appropriate sanitation practices like weed removal helps alleviate whitefly problems in subsequent cropping cycles. Manage

whiteflies during transplant production to avoid introducing whiteflies to production greenhouses or to the field; for more information on controls on transplants see whiteflies in the Insect and Mite Management section of Vegetable Transplants.

Scout weekly by checking the undersides of 1 to 2 leaves on 10 to 20 plants throughout the greenhouse. Use yellow sticky cards to capture whitefly adults. Hang traps near the tops of the plants, 1 to 4 cards every 1,000 sq ft of greenhouse. Check and replace weekly, recording the number of adults per card. Use this information to decide if natural enemy releases or insecticides are needed.

As with all biological controls, it is important to begin releases early, before the pest builds up, and continue releases as the crop grows. The parasite *Encarsia formosa* has been successfully used to control greenhouse whiteflies on greenhouse tomato and other crops. The parasite *Eretmocerus eremicus* is used for control of sweet potato whitefly. Please consult the following guides for more information biology and monitoring of whiteflies in greenhouse crops and how to integrate cultural practices, biological control and pesticides: The New England Floriculture Guide and the Penn State Manual Greenhouse IPM with and Emphasis on Biocontrols.

buprofezin (Talus 70DF): 6 to 9 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16.* Apply by ground on 2-acre minimum with 20 gallons water per acre.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M.*

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; *PHI 0d, REI 4h, Bee: M.*

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; *PHI 1d, REI 12h, Bee: H, Group 28.*

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; *PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A.* Do not apply to varieties with fruit that is less than 2", such as cherry or grape tomatoes.

imidacloprid (Admire Pro): 0.6 oz/1,000 plants; *PHI 0d, REI 12h, Bee: H, Group 4.* Use on mature plants only. Apply in a minimum of 16 gal water. Do not apply to plants grown in non-soil media.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. Repeat application every 2 to 3 days until pest is under control.

***Metarhizium anisopliae* Strain F52 (Met 52 EC):** 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L.*

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

pyriproxyfen (Distance IGR): 6 oz/100 gal; *PHI 1d, REI 12h, Bee: L, Group 7D.* Apply as a foliar spray. Do not apply to tomato varieties less than 1" in diameter, such as cherry or grape tomatoes.

PHYSIOLOGICAL DISORDERS

■ Blotchy Ripening

See Blotchy Ripening section of Tomato (Outdoor).

■ Blossom End Rot

See Blossom End Rot section of Tomato (Outdoor).

■ Fruit Cracking

Fruit cracking in tomatoes can be a serious market problem, reducing profits. This can range from splitting to skin russetting. The causes of fruit cracking are varied and are subject to debate by researchers. Several factors have an effect on fruit cracking. Water uptake, humidity, temperature, and soluble solids (sugars) as well as calcium nutrition and standing water on the fruit are thought to have roles in fruit cracking, along with genetics. Cultural practices that can have an effect on fruit cracking include water management and light levels. The rate of fruit development can be affected by management practices. Irregular water uptake going from very dry to very wet plays a major role in fruit cracking. High temperatures also play a role. Irrigation can be used to modify both. Growers can increase the frequency of irrigation to prevent moisture extremes from developing under both field and greenhouse conditions. Overhead irrigation can also be timed to cool the crop in extreme conditions. High humidity and calcium nutrition are also associated with fruit cracking. Management practices must allow good transpiration rates as well as adequate calcium levels in the soil or fertilizer solution. Likelihood of cracking increases if tomatoes are allowed to fully ripen on the plant. Increased light and fruit growth can occur when new plastic is put on or with topping to increase fruit size. Watering schedules may need to be modified to reduce cracking under those conditions.

TOMATO, OUTDOOR

Tomato (*Solanum lycopersicum*) is a warm season crop of the nightshade family (*Solanaceae*), along with pepper, eggplant, and potato. Tobacco, petunia, nicotiana, and several important weed species are also solanaceous. Tomato is native to South America, with its use as a food crop originating in Mexico. It grows best on well-drained soils that are high in organic matter. It is frost-sensitive and should be transplanted into fields once the soil has warmed.

Types and Varieties (chart page 310)

There are thousands of tomato cultivars available, and varieties might be selected based on market preferences for shape, color and flavor, as well as for ease of harvest and storage, and for tolerance or resistance to the many diseases that affect this crop.

Indeterminate varieties produce stems that will continue to grow until killed by frost. They perform best when staked or trellised. Side shoots and suckers arising from the base of the plants should be pruned off weekly and the main stem should be secured to the stake. Indeterminate cherry, grape and some plum/“saladette” vines are often more vigorous than indeterminate slicing tomato vines.

Determinate varieties have stems that grow long enough to produce 2-3 flower clusters and then stop. It is necessary to

allow the suckers to grow to produce more flowers and fruit per plant. Determinate varieties are well-suited for ground, cage or basket weave culture.

Several tomato varieties can be classified as “vigorous determinates,” and are important commercial production varieties. They produce a higher percentage of grade A fruits when they are staked. Under good conditions, they can produce 15-20 lbs. per plant, but require more space.

Varieties that are later maturing are of higher market quality than the earlier varieties, but early varieties are important for early-season customer attraction. Cherry tomatoes are appealing throughout the production year, as are “cocktail” and “saladette” types. Interest in the less juicy paste/Roma-type fruits is usually during late summer to early fall.

Most varieties used by commercial growers are hybrids, generally labeled (F1), which are crosses produced by controlled pollination between 2 different varieties to select for the desirable characteristics of each. Seed produced by F1 hybrids are not genetically stable and tend not to breed true if saved. Plants produced from hybrid seed tend to be more productive and vigorous, and may be bred for resistance to specific diseases.

Heirloom/Open-Pollinated varieties are very popular in the marketplace. A diverse array of varieties are available and many growers create their own market identities by reliably producing them. Most heirloom varieties carry little or no disease resistance. *Verticillium*, *Fusarium*, *Alternaria* and *Septoria* can be particularly problematic. Cultural practices like field rotations and good sanitation are essential.

Recently, a number of “hybrid heirlooms” have been introduced. These have appearance and flavor similar to heirlooms, but also have more resistance to leaf spot and vascular pathogens and are not as subject to as much variability in fruit size and shape.

Soil Fertility

Apply lime according to soil test results to maintain soil pH at 6.5-6.8. Maintain high calcium. Base saturation for calcium should be 65%-80%. Use calcitic lime or gypsum if necessary.

When growing plants on plastic mulch, the amount of nitrogen fertilizer to be sidedressed can be reduced, and most of it can be applied when laying the plastic, since leaching is minimized. Leaf tissue testing can be an important tool to monitor the nutrient status of your plants. If testing is done at the right time (early to mid bloom), additional nutrients, most importantly N and K, can be supplemented. While these can be side-dressed along the edge of the plastic mulch, nutrients can be applied more effectively in soluble form through drip irrigation installed under the plastic. Liquid suspensions of organic nutrients can be applied this way as well, but drip lines should be flushed regularly. If this method is used, apply no more than 10 lbs. per week of actual nitrogen fertilizer per acre.

A thirty-ton tomato yield removes about 200 pounds of nitrogen per acre while a fifteen-ton yield removes about 100 pounds of nitrogen per acre. On the “Plant Nutrient Recommendations” table (page 311), the nitrogen recommendation for outdoor tomatoes is figured on a yield goal of twenty-two tons per acre. Do not apply more nitrogen

fertilizer than is required to achieve your realistic yield goal. Excess nitrogen can reduce yield. Use a high P liquid starter fertilizer at transplanting, especially with cool soil conditions.

Less nitrogen fertilizer will be needed on some soils high in organic matter, or if legume sod was plowed down or manure was applied (see Table 1, pg. 2 and Table 7, pg. 15).

When side-dressing nitrogen, the nitrate forms (such as calcium nitrate) are preferred over the ammonium or urea forms. While maintaining adequate calcium in the soil is essential, blossom end rot is a physiological disorder in which the plants allocate more calcium to vegetative growing

tips than to developing fruit. It usually occurs during the early ripening period, and much more commonly on Roma-type tomatoes. Adequate irrigation is essential during this time.

Planting

Tomatoes are transplanted in New England due to the short growing season. Early fruit production requires quality transplants. Adequate spacing produces short, stocky plants with good root systems, whereas crowding produces tall, spindly plants. One ounce of tomato seed will produce about 7,400 plants.

Tomato Varieties				
Fruit Type	Variety	Season/Size	Growth Habit	Disease Resistances*
Hybrid Slicing	Be Orange	Main/Large	Indeterminate	V, F1, F2, FCRRR, LM, TomMV
	BHN 589	Main/Large	Vigorous Determinate	V, F2, TMV
	Big Beef	Main/Large	Indeterminate	V, F1, F2, St, TMV, N
	Early Girl	Early/Medium	Indeterminate	V, F1, F2
	Geronimo	Main/Large	Indeterminate	V, F1, F2, TMV, LM, PM
	Manitoba	Early/Small-Medium	Compact Determinate	V, F
	Mountain Fresh Plus	Main/Large	Vigorous Determinate	V, F1, F2, N, EB, GW, BER
	Mountain Merit	Early/Large	Compact Determinate	V, F1, F2, N, TSWV, EB, LB
	New Girl	Early/Small-Medium	Indeterminate	V, F1, F2
	Primo Red	Early/Large	Compact Determinate	V, F1, F2, TMV
Red Deuce	Main/Large	Vigorous Determinate	V, F1, F2, TMV, St	
Heirloom/OP	Amish Paste	Variable Plum	Indeterminate	None
	Black Krim	Early/Medium	Indeterminate	LB
	Brandywine	Main/Large	Indeterminate	EB, FB
	Cherokee Purple	Main/Large	Indeterminate	BS, F1, F2, F3, N, TSWV
	Green Zebra	Early/Small	Vigorous Indeterminate	LB, SLS
	Principe Borghese	Small oval cherry	Vigorous Indeterminate	None
	Pruden's Purple	Main/Large	Indeterminate	None
	San Marzano II	Elongated plum	Indeterminate	F, N, TomMV
	Striped German	Main/Large	Indeterminate	Unknown
Yellow Pear	Early pear-shaped cherry	Vigorous Indeterminate	None	
"Hybrid Heirloom"	Caiman	Main/Large	Indeterminate	F1, N, LM, TomMV, TMV, TSWV, V
	Damsel	Main/Large	Indeterminate	LB, N, V
	Marbonne	Main/Large	Indeterminate	F1, TomMV
	Margold	Main/Large	Indeterminate	LM, TomMV, V
	Marnero	Main/Large	Indeterminate	F1, EB, FCRRR, TomMV, V
Hybrid Paste/Plum	Golden Rave	Early/Small-Medium	Vigorous Indeterminate	F, F1, TomMV, TMV
	Granadero	Main/Medium	Indeterminate	V, F1, F2, TMV, PM, N, TSWV
	Juliet	Early/Small	Vigorous Indeterminate	EB, LB, SLS
	Plum Regal	Main/Medium	Vigorous Determinate	EB, F1, F2, LB, TSWV, V
	Verona	Early/Medium	Indeterminate	V, F1, F2
Hybrid Cherry	Black Cherry	Large	Vigorous Indeterminate	None
	Favorita	Medium	Vigorous Indeterminate	F2, N, LM, TMV
	Sakura	Large	Vigorous Indeterminate	F1, F2, N, LM, TMV
	Sun Peach	Medium	Vigorous Indeterminate	LM, TMV
	Sungold	Small-Medium	Vigorous Indeterminate	F1, F2, TMV, V
	Sunsugar	Medium	Vigorous Indeterminate	F1, V

*Resistance Key: EB=Early Blight; LB=Late Blight; SLS=Septoria Leaf Spot; F1, F2, F3=Fusarium race 1,2,3; TomMV=Tomato Mosaic Virus; TMV=Tobacco Mosaic Virus; TSWV=Tomato Spotted Wilt Virus; LM=Leaf Mold; PM=Powdery Mildew; V=Verticillium; FCRRR=Fusarium Crown Rot and Root Rot; N=Root Knot Nematode

Sow tomato seed in an open flat in germination mix and maintain uniform moisture and bottom heat at 75°F until emergence. Transplant young seedlings into 2"-4" cells or pots when they have two or three true leaves. Choice of pot size depends on weeks before anticipated field transplant date. For earliest production, some growers finish their transplants in 6" (or even larger) pots.

Grow transplants at 70°-75°F day and 60°-65°F night temperatures. Night temperatures in the greenhouse below 60°F may result in irregular fruit (catfacing) on the first few clusters. Five to 8 weeks from seed are required to produce field-ready transplants, depending on the temperature at which the plants are grown and the size desired. Avoid the temptation to start the plants too early; holding them for too long will reduce yield. Harden only slightly, by reducing water and nutrients, and ambient temperature, if possible but not below 60°F. Small plants that have been slightly hardened, or not hardened at all, will outperform larger, over-hardened plants.

Transplants should be given a complete nutrient solution supplemented with trace elements (the latter especially if artificial mixes are used) at weekly intervals. Alternatively, they can be fed whenever they are watered with a dilute nutrient solution. The advantage to the latter system is that the fertilizer is supplied more in relation to the plant's needs: more on bright, warm days; less on cool, cloudy days. In either case, follow directions on the fertilizer label for amounts to feed. Use a soluble fertilizer and be careful of salt buildup. It is advisable to use a fertilizer in which most of the nitrogen is in the nitrate form rather than ammonium or urea.

Field Culture

Many growers use black plastic mulch, which has several benefits. It warms the soil, promotes early production, conserves water, permits use of less nitrogen fertilizer because leaching is reduced, and facilitates weed control. Plastic mulch also keeps most of the fruit off the soil. The disadvantages of plastic mulch are removing the plastic in the fall and disposing of it. Plastic should be laid tightly over the beds to conduct heat to the soil more efficiently and to avoid depressions where puddles can form. Many growers use plastic mulch in conjunction with raised beds. This warms the soil more quickly. Prior to laying plastic mulch, soil moisture should be at or near field capacity. Trickle irrigation with a fertilizer injector, is a very efficient watering method used under black plastic mulch. Consistent soil moisture reduces or eliminates problems with blossom end rot and cracking. Row covers over wire hoops are used by some growers for faster early season growth. They do not provide significant frost protection, but they do speed

growth. Ventilation is usually needed on warm, sunny days. Do not allow temperatures under covers to exceed 90°F. (See Plastic Mulch and Row Covers, page 31, and High Tunnels, page 33.)

Trellising/Staking

Staking or trellising certain varieties may advance production by 7-10 days. Early tomatoes usually bring higher prices, but this has to be weighed against trellising labor. Fruit quality and plant health may be enhanced by keeping fruit off of the ground and allowing air movement into the plant canopy, reducing the incidence of Anthracnose ripe rot on fruit, and foliar disease spread. Pruning (removing the side shoots) should be done frequently for fully indeterminate varieties. Shoots are most easily removed when they are a few inches long. To reduce disease, do not prune during wet weather or if bacterial canker is present. Indeterminate plants are well suited to trellising or staking because the main stem keeps growing. The plants can be pruned to 1 or 2 stems. For 2 stems, keep the lateral branch just below the first cluster. Two stems obviously yield more fruit per plant than a single stem, but pruning is more time-consuming and each plant requires more space. For trellising, plants are supported by weather-resistant twine tied to a number 9 or 11 wire, 5'-6' above the ground. The wire is held up by posts spaced 20'-30' apart in the row. Metal fence posts help to support the wire, with sturdy wooden posts at the end. Most growers use the "A" trellis, a double row 18"-24" apart. The "A" trellis uses fewer posts and less wire; fruit tends to be more shaded and sun scald is less of a problem. The lower end of the twine is tied loosely around the base of the stem. As the plants grow, the string is spiraled around the main stem. Pruning is usually done at the same time. For staking, plants are tied (3-4 times) to individual stakes. Avoid damage to plants during trellising and staking operations.

Ground Culture and Basket Weave

The stems of fully determinate tomatoes stop growing after producing 1-3 flower clusters. For continued production, side shoots must be left on the plant. This results in a bushy, compact plant which is not suitable for staking or trellising.

Determinate varieties can be grown on the ground without support; vigorous determinate varieties are usually supported using a system called stake and weave or basket weave. With this system, wooden stakes 4'-5' long and 1" square, or similar lengths of rebar, are driven 1' into the ground between every other plant. Weather-resistant twine is then tied to the end stake and run down one side of the row, wrapping the twine around each stake. Most growers weave the twine back and forth between plants. The process is then

Plant Nutrient Recommendation According to Soil Test Results for Outdoor Tomato

OUTDOOR TOMATO	Nitrogen (N) Lbs per acre	Phosphorus (P) Lbs P ₂ O ₅ per acre				Potassium (K) Lbs K ₂ O per acre			
		Very Low	Low	Optimum	Above Optimum	Very Low	Low	Optimum	Above Optimum
Broadcast and Incorporate	80-100	180	120	0-60	0	250	150	50-100	0-50
Sidedress 3-4 Weeks after Planting	30	0	0	0	0	0	0	0	0
Sidedress 6-8 Weeks after Planting	30	0	0	0	0	0	0	0	0
TOTAL RECOMMENDED	140-160	180	120	0-60	0	250	150	50-100	0-50

repeated on the other side of the row. The stringing operation is repeated 3-4 times with the first being 8"-10" above the ground when the plants are 12"-15" tall. Subsequent stringings are made just before the plants begin to fall over. There are many variations of this system. NOTE: birds cannot perch on the rebar, resulting in a cleaner crop at harvest than if using wooden stakes.

Twine should be resistant to weather and stretching. Tomato twine for this purpose is available in 3 or 4-pound boxes. A home-made stringing tool should be used for convenience. It is simply a length of metal or plastic conduit. The twine is fed through the conduit which acts as an extension of the worker's arm.

Most growers remove all the bottom side shoots up to, but not including, the one below the first flower cluster. After this, no pruning is done.

Spacing

Plant spacing will vary according to cultivar and type of culture. Frequent roadways may be necessary to drive spray or harvest equipment between blocks of rows.

Staked: Set plants 12"-18" apart in rows when pruning to a single stem, 18"-24" apart when pruning to 2 stems, and 5' between rows.

Stake and Weave: 5'-6' between rows, 18"-24" between plants.

Ground: For small-vined (determinate) varieties, 4'-6' between rows, set plants 12"-24" apart within the row and for large-vined (vigorous determinate and indeterminate) varieties, set plants 2'-3' apart in the row and 5'-7' between rows. Remember that there will be significant losses due to fruit rots if indeterminates are left unstaked.

High Tunnels

High tunnels (see High Tunnels, page 33, and Tomato (Greenhouse) sections) allow for planting up to four weeks earlier than in the open field. Harvest is earlier and yields are usually greater. High tunnels keep rain off the foliage and fruit, resulting in fewer foliar diseases and rain check (a russetting of the fruit). Sides are rolled up during warm weather, but should be lowered when temperatures fall below 60°F.

Irrigation

If there are no restrictions, tomatoes develop a deep root system. When irrigating tomatoes grown on black plastic, sufficient water must be applied so that lateral water movement can take place under the plastic to provide adequate moisture to the root system. Watering should be deep and spread out across the bed. This can be accomplished by running at least two drip tapes per bed. Once fruit begin to enlarge, tomatoes require at least 1" of water per week depending on temperature, wind and relative humidity. (See also Trickle or Drip Irrigation, page 28.)

Harvest and Storage

Since most tomatoes are marketed in the New England area, it is recommended that tomatoes be harvested at the breaker to turning stage. Tomatoes harvested in the green stage do not promote the image of high quality as implied by the native tomato designation. Letting the fruit ripen completely on the vine improves the flavor somewhat. However, as tomatoes remain on the vine, they are subject to cracking

and other disorders. Jointless varieties have no joint (looks like a knuckle) on the fruit stem. When picking, the stem separates completely from the fruit. These varieties work well for bulk packaging because stemless fruit do not puncture other fruits in the box. With jointed varieties, the stem usually breaks at the joint, leaving a small stem attached to the fruit. This makes for an attractive retail item but requires special handling and more boxes, since fruits cannot be layered on top of each other.

Tomatoes are susceptible to chilling injury if stored at temperatures below 50°F for more than 24 hours. Continual exposure to these temperatures will prevent normal ripening even after temperatures are elevated. Store tomatoes at 55°F or above depending upon how long they must be stored. The speed of color development will increase up to 75°F. Temperatures above 80°F will inhibit red color development. For best eating quality, ripening and color development should take place between 65° and 70°F. Late in the season when night temperatures routinely drop below 50°F, tomatoes should be harvested in the breaker stage and ripened at room temperature.

DISEASE CONTROL

NOTE: For the disease control products listed below, one product trade name and formulation is provided for each active ingredient (common name) as an example of rate, preharvest interval (PHI), REI, and special instructions. In many cases, there are other products available with the same active ingredient. See Fungicides and Bactericides Alphabetical Listing by Trade Name (page 80) and Table 25 (page 84) for more information on products with the same active ingredients.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Anthracnose (*Colletotrichum species*)

Anthracnose is a problem on fruit when it ripens on the plant, but the fungus can also invade the stem tissues resulting in premature death. Rotate crops such that non-host crops are grown at least every other year. Control weed hosts. Stake plants or use mulch to reduce fruit contact with soil. Avoid overhead irrigation. Harvest fruit regularly to avoid excessively ripe fruit. Apply fungicides according to a disease forecasting system (i.e., TOMCAST). Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu).

azoxystrobin (Quadris): 6.0 to 15.0 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides. See label for precautions.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; PHI 0d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 8.0 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

azoxystrobin plus flutriafol (Toppard EQ): 4.0 to 8.0 oz/A; PHI 0d, REI 12h, Groups 3 & 11. See label for tank mix precautions.

chlorothalonil (Bravo Weather Stik): 2.0 to 2.75 pt/A; PHI 0d, REI 12h, Group M5.

chlorothalonil plus phosphorous acid (Catamaran): 7.0 pt/A; PHI 0d, REI 12, Groups M5 & 33. Apply to fruit. See label for restrictions.

chlorothalonil plus zoxamide (Zing!): 36.0 fl oz/A; PHI 7d, REI 12, Groups M5 & 22.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 fl oz/A; PHI 0d, REI 12h. Groups 7 & 3. Do not make more than 2 applications before switching to a non-Group 7 fungicide.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 0d, REI 12h, Group 3 & 9. Do not use on varieties where the mature fruit is less 2 inches (cherry tomatoes).

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action and alternated with a fungicide from a different group (FRAC Code) after one application.

flutriafol (Rhyme): 5.0 to 7.0 fl oz/A; PHI 0d, REI 12, Group 3.

fluxapyroxad plus propiconazole (Priaxor): 4.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Groups 7 & 11.

hydrogen dioxide plus peroxyacetic acid (Oxidate 2.0^{OG}): 0.25 to 2.5% v/v solution; PHI 0d, REI 1h, Group 33. Labeled as preventive and curative. See label for specific application instructions and dilution rates.

mancozeb (Dithane DF Rain Shield): 1.2 to 2.4 qt/A; PHI 5d, REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 1.7 lb/A (processing); 1.0 to 3.0 lb/A (fresh market); PHI 5d, REI 48h, Groups M3 & M1.

mandipropamid plus difenconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12h, Groups 40 & 3. Addition of a spreading/penetrating adjuvant is recommended.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

pyraclostrobin (Cabrio EG): 8 to 12 oz/A; PHI 0d, REI 12h, Group 11. Apply only 6 applications per season or 96 oz/A. Do not rotate with other Group 11 fungicides.

tetraconazole (Mettle 125ME): 6.0 to 8.0 oz/A; PHI 0d, REI 12h, Group 3. Begin application before disease onset. Make no more than 2 consecutive applications. See label for restrictions.

ziram (Ziram 76 DF): 3 to 4 lb/A; PHI 7d, REI 48h, Group M3. Do not use on cherry tomatoes. See label for restrictions.

■ Gray Mold (*Botrytis cinerea*)

Grey mold is a common disease of tomato and is particularly damaging in greenhouses where the relative humidity is high. The pathogen infects leaves, stems, petioles, and fruit. Ghost spots develop when the pathogen invades the fruit then ceases growth prior to causing decay; the resulting white to yellow rings make fruit unmarketable. Injured transplants can develop gray mold infections of the stem which girdle the plant and cause plant death. Reduce plant wetness by avoiding overhead irrigation. Fungicides are

useful in protecting fruit; a diversity of fungicides with different modes of action must be used as *Botrytis* commonly develops fungicide resistance. Many products labeled for leaf spots will also provide some control for gray mold. See: Leaf Spots, below.

***Ulocladium oudemansii* (BotryStop^{OG})**: 2.0 to 4.0 lbs/A; PHI 0d, REI 4h, Group NC. Begin application when conditions are conducive to disease development.

■ Leaf Spots: Early Blight (*Alternaria solani*) and Septoria leaf spot (*Septoria lycopersici*)

Early blight and Septoria leafspot are very destructive of tomato. Both diseases may occur together, and both may be seed-borne. Hot water treat seeds at 122°F for 25 minutes. Plow under plant debris after harvest. Rotate away from tomatoes for at least 2 years. Provide optimum nutrition throughout the season. If planting in an area with a history of either disease, begin fungicide applications before disease is evident, usually when first fruit are half grown or approximately the first week of July. Follow fungicide intervals recommended by a disease forecasting system (TOMCAST) if weather and forecast data are available in your region. Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu).

azoxystrobin (Quadris): 5 to 6.2 fl oz/A; PHI 0d, REI 4h, Group 11. Do not apply more than 1 application of Quadris before alternating with a fungicide that has a different mode of action. See label for other precautions.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; PHI 0d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus difenoconazole (Quadris Top): 8.0 fl oz/A; PHI 0d, REI 12h, Groups 11 & 3.

azoxystrobin plus flutriafol (Topguard EQ): 4.0 to 8.0 oz/A; PHI 0d, REI 12h, Group 3 & 11.

***Bacillus mycooides* Isolate J (LifeGard^{OG})**: 4.5 oz/100 gal water; PHI 0d, REI 4, Group P6.

***Bacillus pumilis* Strain QST 2808 (Sonata^{OG})**: 2.0 to 4.0 qt/A; PHI 0d, REI 4, Group 44.

***Bacillus subtilis* Strain QST 713 (Serenade Opti^{OG})**: 14.0 to 20.0 oz/A; PHI 0d, REI 4, Group 44. Not for Septoria leaf spot.

chlorothalonil (Bravo Weather Stik): 1 3/8 to 2.0 pt/A; PHI 0d, REI 12h, Group M5.

chlorothalonil plus phosphorous acid (Catamaran): 4.5 to 5.0 pt/A (foliage), 7.0 pt/A (fruit); PHI 0d, REI 12h, Groups M5 & 33.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 12.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 fl oz/A; PHI 0d, REI 12. Groups 7 & 3. Do not make more than 2 applications before switching to a non-Group 7 fungicide.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 0d, REI 12h, Group 3 & 9. Do not use on varieties where the mature fruit is less than 2 inches (cherry tomatoes).

famoxadone plus cymoxanil (Tanos): 6.0 to 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action and alternated with a fungicide from a different group (FRAC Code) after one application. Do not alternate with Quadris, Cabrio, or Flint.

fenamidone (Reason 500 SC): 5.5 to 8.2 fl oz/A; PHI 14d, REI 12h, Group 11. Do not make more than one application before rotating to a fungicide from a different resistance management group (not Group 11).

fluopyram plus pyrimethanil (Luna Tranquility): 11.2 fl oz/A; PHI 1d, REI 12h, Group 7 & 9.

flutriafol (Rhyme): 3.5 to 7.0 fl oz/A; PHI 0d, REI 12, Group 3.

fluxapyroxad plus propiconazole (Priaxor): 4.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Groups 7 & 11.

hydrogen dioxide plus peroxyacetic acid (Oxidate 2.0^{OG}): 0.25 to 2.5% v/v solution; PHI 0d, REI 1h, Group P7. Use as a preventive or curative. See label for application instructions and specific dilution rates.

mancozeb (Dithane F45): 1.2 to 2.4 qt/A; PHI 5d, REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 1.7 lb/A (processing); 1.0 to 3.0 lb A (fresh market); PHI 5d, REI 48h, Groups M3 & M1.

mancozeb plus zoxamide (Gavel 75DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48h, Groups M3 & 22. Add Latron surfactants to improve performance.

mandipropamid plus difenconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12h, Groups 40 & 3. Addition of a spreading/penetrating adjuvant is recommended.

penthiopyrad (Fontelis): 16.0 to 24.0 fl oz/A; PHI 0d, REI 1h, Group 7.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propamocarb HCl (Previcur Flex): 0.7 to 1.5 pt/A; PHI 5d, REI 12h, Group 28.

pyraclostrobin (Cabrio EG): 8.0 to 12.0 oz/A; PHI 0d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

pyrimethanil (Scala SC): 7.0 fl oz/A; PHI 1d, REI 12h, Group 9. Use only in a tank mix with another fungicide labeled for control of early blight. Using with a protectant fungicide (M3 or M5) will expand the spectrum of activity adding control of late blight and Septoria leaf spot.

tetraconazole (Mettle 125ME): 6.0 to 8.0 oz/A; PHI 0d, REI 12h, Group 3. Begin application at onset of disease. Do not make more than two consecutive applications before switching to different Group.

trifloxystrobin (Flint): 2.0 to 3.0 oz/A; PHI 3d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

ziram (Ziram 76 DF): 3.0 to 4.0 lb/A; PHI 7d, REI 48h, Group M3.

■ Late Blight (*Phytophthora infestans*)

Protectant fungicides are a key tool for management; however, many strains of *P. infestans* have become resistant to mefenoxam. When resistant strains are present, some newer foliar fungicides (higher group numbers) will give as much, or more protection, against late blight as mefenoxam combinations. Several forecasting systems can be used for identifying late blight infection periods. Disease development, based on weather conditions near your farm, can be monitored on-line (www.newa.cornell.edu). Disease progression throughout the US can also be monitored (www.usablight.org). Avoid the use of overhead irrigation. Promptly plow under old tomato fields after harvest. Eliminate cull piles and volunteer plants of both tomato and potato. Some resistant cultivars are available.

ametoctradin plus dimethomorph (Zampro): 14.0 fl oz/A; PHI 4d, REI 12h, Groups 45 & 40.

azoxystrobin (Quadris): 6.2 fl oz/A; PHI 0d, REI 4h, Group 11. Do not rotate with other Group 11 fungicides. See label for precautions.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; PHI 0d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

***Bacillus amyloliquefaciens* strain D747 (DoubleNickel 55^{OG}):** 0.25 to 3.0 lb/A; PHI 0d, REI 4 h, Group 44. Use for disease suppression only. For improved control; mix or rotate with a chemical fungicide.

***Bacillus mycooides* Isolate J (Lifegard^{OG}):** 4.5 oz/100 gal of water/A; PHI 0d, REI 4h, Group P6.

chlorothalonil (Bravo Weather Stik): 1 3/8 to 2.0 pt/A; PHI 0d, REI 12h, Group M5.

chlorothalonil plus phosphorous acid (Catamaran): 4.5 to 5.0 pt/A (foliage), 7.0 pt/A (fruit); PHI 0d, REI 12h, Groups M5 & 33.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette.

cyazofamid (Ranman): 2.1 to 2.75 fl oz/A; PHI 0d, REI 12h, Group 21. Begin applications when forecast systems (NEWA) predict disease infection periods. Use the lowest rates and longest intervals when disease pressure is low. Use the highest rates and shortest spray intervals when late blight is present in the area. Do not make more than 3 consecutive sprays, then follow with three or more applications of fungicides with a different Group #. If other diseases are present, tank mix with a Group M3 or M5 fungicide.

cymoxanil (Curzate 60 DF): 3.2 to 5.0 oz/A; PHI 3d, REI 12h, Group 27. Use only in combination with a labeled rate of a protectant fungicide (copper, chlorothalonil).

cymoxanil plus chlorothalonil (Ariston): 1.9 to 3.0 pt/A (foliage); 1.9 pt/A (fruit); PHI 3d, REI 12h, Groups 27 & M5.

dimethomorph (Forum): 6 fl oz/A; PHI 4d, REI 12h, Group 40. Must be applied as a tank mix with another fungicide

with a different mode of action. Do not make more than two consecutive applications of Forum before alternating to a non-Group 15 fungicide.

famoxadone plus cymoxanil (Tanos): 8.0 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action and alternated with a fungicide from a different group (FRAC Code) after one application.

fenamidone (Reason 500 SC): 5.5 to 8.2 fl oz/A; PHI 14d, REI 12h, Group 11. Do not make more than one application before rotating to a fungicide from a different resistance management group (not Group 11).

fluopicolide (Presidio): 3.0 to 4.0 fl oz/A; PHI 2d, REI 12h, Group 43. Must be tank mixed with a fungicide with a different mode of action.

mancozeb (Dithane Rain Shield F45): 1.2 to 2.4 qt/A; PHI 5d, REI 24h, Group M3.

mancozeb plus copper hydroxide (ManKocide): 1.7 lb/A (processing); 1.0 to 3.0 lb A (fresh market); PHI 5d, REI 48h, Groups M3 & M1.

mandipropamid plus difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12h, Groups 3 & 40. The addition of a spreading/penetrating type adjuvant is recommended

mefenoxam plus chlorothalonil (Ridomil Gold Bravo): 2.5 pt/A; PHI 5d, REI 48h, Groups 4 & M5.

mefenoxam plus manzate (Ridomil Gold MZ): 2.5 lb./A; PHI 5d, REI 48h, Groups 4 & M3. Do not plant any crop which is not registered for use with Ridomil Gold active ingredient in treated soil for a period of 12 months.

oxathiapiprolin plus chlorothalonil (Orondis Opti): 1.75 to 2.25 pt/A; PHI 0d, REI 12h, Groups M5 & 49.

oxathiapiprolin (Orondis Ultra A): 2 to 4 fl oz/A; PHI 0d, REI 4h, Group 49.

phosphorus acid (ProPhyt): 4.0 pt/A; PHI 0d, REI 4h, Group 33. Apply at first report of late blight in your area and use shortest interval. Thorough coverage is essential. Apply in tank mix with contact products like chlorothalonil (Group M5) or mancozeb (Group M3). Read label: rates vary between products.

polyoxin D (OSO 5% SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

propamocarb HCl (Previcur Flex): 0.7 to 1.5 pt/A; PHI 5d, REI 12h, Group 28.

pyraclostrobin (Cabrio EG): 8.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11. Do not rotate with other Group 11 fungicides.

trifloxystrobin (Flint): 4.0 oz/A; PHI 3d, REI 12h, Group 11. Apply in a tank mixture with 75% of a labeled rate of a protectant fungicide. Do not rotate with other Group 11 fungicides.

zoxamide + chlorothalonil (Zing!): 36.0 fl oz/A; PHI 5d, REI 12h, Groups 22 & M5.

zoxamide plus mancozeb (Gavel 75 DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48h, Groups 22 & M3.

■ **Phytophthora Blight and Fruit Rot (*P. capsici*) and *Pythium* species)**

Phytophthora fruit infections are called buck-eye rot and *Pythium* fruit infections, which usually infect ripe fruit, are called watery rot. To avoid fruit rots, keep plant tops dry by avoiding overhead irrigation or by using buried drip irrigation. Prepare the soil and beds to enhance drainage and avoid planting in low areas. Stake plants and/or use mulches to minimize fruit contact with the soil. Fungicides may be used to control crown, foliar, and fruit infections. See Late Blight and Pepper *Phytophthora* sections.

■ **Powdery Mildew (*Oidium neolycopersici*)**

Powdery mildew is a relatively new disease of tomato in the Eastern United States. It is more common in the greenhouse than in the field, but in either case it can cause early plant senescence and reduced yields. Powdery mildews are obligate parasites and survive on overwintering tomato, alternate weed hosts, or perhaps as sexual fruiting bodies. Promptly plow under tomato crop debris after harvest. Control volunteer tomatoes and Solanaceous weeds.

azoxystrobin (Quadris): 5.0 to 6.2 oz/A; PHI 0d, REI 14h, Groups 11.

azoxystrobin plus chlorothalonil (Quadris Opti): 1.6 pt/A; PHI 0d, REI 12h, Groups 11 & M5. See label for tank mix precautions.

azoxystrobin plus flutriafol (Topguard EQ): 4.0 to 8.0oz/A; PHI 0d, REI 12h, Groups 11 & 3. See label for tank mix precautions.

***Bacillus pumilis* Strain QST 2808 (Sonata^{OC}):** 2.0 to 4.0 qt/A; PHI 0d, REI 4, Group 44.

botanical oil (cottonseed, corn, garlic) (Mildew Cure): 1 gal/100 gal water; PHI 0d, REI 0h, Group NC.

cyprodinil plus fludioxonil (Switch 6.25 WG): 11.0 to 14.0 oz/A; PHI 0d, REI 12h, Groups 9 & 12.

difenoconazole plus benzovindiflupyr (Aprovia Top): 10.5 to 13.5 fl oz/A; PHI 0d, REI 12. Groups 7 & 3. Do not make more than 2 applications before switching to a non-Group 7 fungicide.

difenoconazole plus cyprodinil (Inspire Super): 16.0 to 20.0 fl oz/A; PHI 0d, REI 12h, Group 3 & 9. Do not use on varieties where the mature fruit is less than 2 inches (cherry tomatoes).

fluopyram plus pyrimethanil (Luna Tranquility): 11.2 fl oz/A; PHI 1d, REI 12h, Group 7 & 9. For disease suppression. See label for application timing.

flutriafol (Rhyme): 5.0 to 7.0 fl oz/A; PHI 0d, REI 12h, Group 3.

fluxapyroxad plus propiconazole (Priaxor): 6.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Groups 7 & 11.

hydrogen dioxide plus peroxiacetic acid (Oxidate 2.0^{OC}): 0.25 to 2.5% v/v solution; PHI 0d, REI 1h, Group P7. Use as a preventive or curative. See label for application instructions and specific dilution rates.

mandipropamid plus difenoconazole (Revus Top): 5.5 to 7.0 fl oz/A; PHI 1d, REI 12h, Groups 3 & 40. The addition of a spreading/penetrating type adjuvant is recommended.

metrafenone (Vivando): 15.4 fl oz/A; PHI 0d, REI 12 hr, Group U8.

myclobutanol (Rally 40WSP): 2.5 to 4.0 oz/A; PHI 0d, REI 24h, Group 3. Observe a 30-day plant-back interval between last spray and the planting of new crops.

paraffinic oil (JMS Stylet-Oil): 3.0 to 6.0 qt/100 gal water; PHI 0d, REI 4h, Group NC. Spray for thorough coverage of upper leaf surface. An organic formulation is available.

polyoxin D (OSO 5%SC): 3.75 to 13.0 fl oz/A; PHI 0d, REI 4h, Group 19.

potassium bicarbonate (MilStop^{OG}): 2.5 to 5.0 lb/100 gal water/A; PHI 0d, REI 1h, Group NC. Use solution within 12 hours of preparation. Thorough crop coverage is required. See label.

sulfur (Microthiol Dispers^{OG}): 5 to 20 lb/A; PHI 0d, REI 24h, Group M2. Do not apply when temperatures will exceed 90°F within three days of application.

tetraconazole (Mettle 125ME): 3.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Group 3. See label for restrictions.

■ White Mold, Sclerotinia Blight (*Sclerotinia* species)

Sclerotinia survives for years in the soil and is particularly destructive to ground tomatoes. Many vegetable crops are hosts. Rotate with corn or other grass species. Do not plant seed that is contaminated with sclerotia (survival structures). Encourage rapid soil drying by irrigating in the morning and/or buried drip irrigation. Avoid excessive nitrogen levels and ensure adequate potassium fertility. Soil sterilization with chemical, steam, or heat treatments (solarization) can significantly reduce sclerotia (inoculum) in the soil. Research has shown promise from incorporating broccoli biomass or brassica cover crops and the biocontrol agent, (NOTE: the current Bayer label for *Coniothyrium minitans* (Contans) does not include tomato).

fluxapyroxad plus propiconazole (Priaxor Xenium): 6.0 to 8.0 fl oz/A; PHI 0d, REI 12h, Groups 7 & 11. Use for suppression only.

fluopyram plus trifloprothoxin (Luna Sensation): 7.6 fl oz/A; PHI 0d, REI 12h, Group 7 & 11. For disease suppression. See label for timing.

***Trichoderma asperellum*, *T. gamsii* (Bio-Tam 2.0^{OG}):** See label for rates an application methods; PHI 0d, REI 4h, Group NC.

pyraclostrobin (Cabrio EG): 12.0 to 16.0 oz/A; PHI 0d, REI 12h, Group 11. Suppression only.

■ Bacterial Canker (*Clavibacter*), Bacterial Speck (*Pseudomonas*), and Bacterial Spot (*Xanthomonas*)

Bacterial canker is the most destructive bacterial disease of tomatoes in our region. All three bacterial diseases may be seed-borne or may overwinter in crop debris in the field. Buy hot-water treated seed or seed certified to be free of bacteria. Hot water seed treatment can be done at home. Treat seed for 25 minutes at 122°F. Some lots of seed can be vulnerable to heat treatment. Always treat a small amount of seed (50 to 100) of each lot before treating the remainder of the lot. See Hot Water Treatment of Seed, page 78. Avoid working in fields when plants are wet. Rotate out of tomatoes for at

least 2 years. Use copper or streptomycin on plants before transplanting. Disinfect stakes before reusing.

acibenzolar-S-methyl (Actigard 50 WG): 0.33 to 0.75 oz/A; PHI 14d, REI 12h, Group 21. Apply to healthy, actively growing plants preventively. Plant defense activator.

***Bacillus mycoides* Isolate J (LifeGard^{OG}):** 4.5 oz/100 gal water; PHI 0d, REI 4, Group P6. (Not labeled for bacterial canker).

***Bacillus subtilis* (Serenade^{OG}):** See labels for specific instructions; REI 4h, Group 44.

***Bacillus subtilis* v. *amyoliquefaciens* (Taegro ECO^{OG}):** 2.6 to 5.2 oz/A; PHI 0d, REI 24h, Group NC.

copper hydroxide (Kocide 3000): 0.75 to 1.75 lb/A; PHI 0d, REI 48h, Group M1. Do not apply in a spray solution having a pH less than 6.5 or tank mix with Aliette. An organic formula (Kocide 3000-O) is available.

copper sulfate (Cuprofix Ultra): Rates and REI vary with products - see labels; PHI 0d, REI 48h, Group M1.

famoxadone plus cymoxanil (Tanos): 8 oz/A; PHI 3d, REI 12h, Groups 11 & 27. Must be tank mixed with an appropriate contact fungicide with a different mode of action and alternated with a fungicide from a different group (FRAC Code) after one application.

mancozeb (Dithane Rain Shield F45): 1.2 to 2.4 qt/A; PHI 5d, REI 24h, Group M3. Use a full rate of fixed copper in a tank mix with half to full rate of Dithane F45.

mancozeb plus copper hydroxide (ManKocide): 1.7 lb/A (processing), 1.0 to 3.0 lb A (fresh market); PHI 5d, REI 48h, Groups M3 & M1.

potassium salts of phosphorous acid plus hydrogen oxide (Oxiphos): 2.5 to 5.0 qt/A; PHI 0d, REI 12h, Group P7. Apply as dilute foliar spray or via irrigation applied immediately after planting. Do not exceed more than 2.5% v/v solution. See label for instructions and restrictions.

streptomycin (Agri-Mycin 17): 0.5 lb/50 gal; REI 12h, Group 25. For use on transplants only, prior to transplanting. NOT for field use.

zoxamide plus mancozeb (Gavel 75 DF): 1.5 to 2.0 lb/A; PHI 5d, REI 48h, Groups 22 & M3. Use full rate of a fixed copper tank mixed with a full rate of Gavel.

■ Cucumber Mosaic Virus (CMV)

Many different strains of this virus occur and the host range includes plants in more than 31 different families. In tomato, the symptoms can be confused with tobacco mosaic as well as other virus diseases. The disease is spread by several species of aphids in a nonpersistent manner. Reduce weeds, especially chickweed, pokeweed, and milkweed, as much as practical. Insecticides will not control this virus. Isolate tomato fields from cucurbits especially where there has been a history of CMV. Resistant varieties cannot be recommended at this time.

■ Tobacco and Tomato Mosaic Virus (TMV, ToMV)

Several strains of TMV exist including the closely related tomato (TomMV) strain. Symptoms on tomato can vary considerably

as will the severity of disease and the effect on yield. Either strain can be seed-borne or transferred from previously infected plant debris, weeds, transplants, other crops, or workers using tobacco products. Unlike other viruses, TMV and TomMV are easily spread from plant to plant by contact with hands and tools. Insects are not considered to be important vectors. Grow resistant varieties. Control weeds as much as practical. Hands and clothes soiled with tobacco or from weeding can transmit the virus. When working with plants, avoid wearing soiled clothes. Wash hands after weeding or smoking. Do not plant susceptible pepper or tomato varieties for at least 2 years on land that previously had TMV-infected crops. Handle plants as little as possible. Do not allow workers to use tobacco products while working with plants.

■ Tomato Spotted Wilt Virus (TSWV)

Do not raise tomato, pepper, eggplant, or cauliflower transplants in the same greenhouse as ornamentals. Monitor thrips and control as necessary. Resistant varieties are not available at this time. The host range for TSWV is one of the largest of any virus. Hundreds of plant species are susceptible including many commercial floriculture crops.

■ Wilt (*Fusarium* and *Verticillium*)

Plant resistant varieties. Pre-plant treatment of soil with effective fumigants will give short-term control but will not completely eliminate the pathogens from fields. Rotate tomatoes with non-host crops such as corn or small grains to lower inoculum levels. Avoid bringing contaminated soil on equipment to new land.

Trichoderma asperellum, *T. gamsii* (Bio-tam 2.0^{OG}): See label for in-furrow, drench, and broadcast rates; PHI 0d, REI 1h, Group NC.

INSECT CONTROL

Insects are seldom serious pests on tomato; be sure there is a problem before sprays are applied. Transplant clean plants to the field; free of aphids, whiteflies, and thrips.

NOTES: For the insecticides listed below, one product trade name and formulation is provided for each active ingredient (AI) as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same AI. See Insecticides Alphabetical Listing by Trade Name (page 92) and Table 27 (page 108) for more information.

The designation (Bee: L, M, or H) indicates a bee toxicity rating of low, moderate, or high. See Protecting Honeybees and Native Pollinators (page 91) for more details.

The symbol * indicates a product is a restricted use pesticide. See Pesticide Safety and Use (page 67) for more details.

The symbol ^{OG} indicates a product is listed by the Organic Materials Review Institute (OMRI) as approved for use in organic production. See Organic Certification (page 41) for more details.

■ Aphids, Potato (*Macrosiphum euphorbiae*) and Green Peach (*Myzus persicae*)

See potato aphid (PA) in the insect control section of Potato section and green peach aphid (GPA) in the insect control section of Pepper for more information on each of these aphid species. Scout for aphids under surfaces of leaves in

both upper and lower foliage. Potato aphids feed first in young growing tips, spreading downward as they multiply. Leaves become distorted, with the leaf edges curling downward. They also feed in blossoms and PA colonies cause blossom drop and fruit deformities. By contrast, GPA feeds first in lower leaves. Scout weekly across the field, sampling 3 leaves per plant at lower, mid and upper levels. Count aphid adults and nymphs and note if numbers are increasing. Treat when aphids exceed 6 per leaf. Beneficials generally keep aphids under control in tomato, unless broad spectrum insecticides are used for other pests. DO NOT use emulsifiable concentrates on tomatoes setting young fruit, or injury may occur.

acetamiprid (Assail 30SG): 2 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 3 fl oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

alpha-cypermethrin (Fastac* EC): 3.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses; PHI 0d, REI 4h, Bee: L, Group un. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake.

bifenthrin (Brigade* 2EC): 2.1 to 5.2 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

***Chromobacterium subtsugae* strain PRAA4-1 (Grandevo^{OG}):** 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection. Suppression only.

dimethoate (Dimethoate 4EC): 0.5 to 1 pt/A; PHI 7d, REI 48h, Bee: H, Group 1B.

dinotefuran (Safari): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; REI 12h, Bee: H, Group 4A. For transplants while in greenhouse. Not for use on greenhouse or field crops.

dinotefuran (Venom): 7 to 14 dry oz/A foliar or 18 to 21 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. Do not apply to varieties with fruit that is less than 2" such as cherry or grape tomatoes.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage.

flupyradifurone (Sivanto): 7 to 12 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare^{*}): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.* Suppression only.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; *PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A.* Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L.* Spray to wet all infested plant surfaces. For enhanced and residual control apply with a companion labeled insecticide.

malathion (Malathion 57EC): 1 to 2.5 pt/A; *PHI 1d, REI 12h, Bee: H, Group 1B.*

methomyl (Lannate^{*} LV): 1.5 to 3 pt/A; *PHI 1d, REI 48h, Bee: H, Group 1A.*

oxamyl (Vydate^{*} L): 2 to 4 pt/A; *PHI 3d, REI 48h, Bee: H, Group 1A.* Apply by ground or air when insects first appear.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L.* Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; *PHI 0d, REI 12h, Bee: L, Group 9B.* Green peach and potato aphids only. Translaminar. Apply when aphids first appear, before populations build up.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A.*

sodium tetraborohydrate decahydrate (Prev-AM): 100 oz/100 gal; *REI 12h, Bee: L, Group 25.* Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23.* Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4C.* Do not apply until after petal fall.

thiamethoxam (Actara): 2 to 3 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A.*

thiamethoxam (Platinum): 5 to 11 oz/A; *PHI 30d, REI 12h, Bee: H, Group 4A.* Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray.

tofenpyrad (Torac): 17 to 21 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A.*

■ Tomato and Tobacco Hornworms (*Manduca quinquemaculata* and *M. sexta*) and other caterpillars

Tomato and tobacco hornworms (THW) are large green caterpillars with white stripes along the sides that may grow up to 4" long. Despite their size and striking appearance, they can be very difficult to find on the plant. It is easier to look for the large fecal droppings on the plastic mulch under

the plants. The caterpillars climb to feed near the tops of the plants just before dusk, and spritzing with water will make them flinch so that they are easy to find and remove. The insect spends the winter as a pupa 2" to 4" under the soil. Caterpillar infestations usually begin in July and may extend through September. When numerous, they can nearly defoliate tomato plants and may even surface feed on the immature green fruit. Fall or early spring plowing will reduce the survival of the pupae. Hornworms only occasionally require treatment and are usually controlled by their natural enemies (braconid wasp, bugs and pathogens). Caterpillars covered with numerous white wasp pupae should be moved to a plant that will not be sprayed to help preserve and build up parasite populations. Spot-treat areas of the field with severe defoliation. It is recommended to use insect growth regulators, microbial products (*Bt*) or other selective insecticides (chlorantraniliprole, emamectin benzoate, indoxacarb, or methoxyfenozide) to preserve natural enemies and avoid secondary pest outbreaks (i.e. aphids).

Tomato fruitworm (TFW) is another name for the corn earworm, which may attack tomatoes and other solanaceous crops late in the season, especially if moth numbers are high and fresh corn silk is relatively scarce. Use selective insecticides to avoid disrupting natural enemies that control secondary pests, such as mites and aphids. For more information, see corn earworm in the Sweet Corn section. Cabbage looper (CL) is an occasional pest of tomato; see Cabbage section for more information.

alpha-cypermethrin (Fastac^{*} EC): 2.2 to 3.8 oz/A fruitworm and hornworm, 3.2 to 3.8 oz/A looper; *PHI 1d, REI 12h, Bee: H, Group 3A.*

***Bacillus thuringiensis* subsp. *aizawai* (XenTari^{OG}):** 0.5 to 1.5 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt kurstaki* products (Dipel).

***Bacillus thuringiensis* subsp. *kurstaki* (Dipel DF^{OG}):** 0.5 to 2 lb/A; *PHI 0d, REI 4h, Bee: L, Group 11.* Must be ingested; apply in evening or early morning, before larvae are actively feeding. Adherence and weather-fastness will improve with use of an approved spreader-sticker. Use high rate at cool temperatures. For resistance management, may be rotated with *Bt aizawai* products (XenTari).

beta-cyfluthrin (Baythroid^{*}XL): 1.6 to 2.8 oz/A for TFW and THW, 2.1 to 2.8 oz/A for CL; *PHI 0d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade^{*} 2EC): 2.1 to 5.2 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.* Looper and fruitworm only.

buprofezin & flubendiamide (Vetiva): 12 to 17 oz/A; *PHI 1d, REI 12h, Bee: L, Groups 16 & 28.*

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate XC^{OG}):** 1 to 8 qt/A; *PHI 0d, REI 4h, Bee: M.*

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; *PHI 1d, REI 4h, Bee: L, Group 28.* May be applied through drip irrigation or as a foliar spray. For soil applications, must be applied uniformly in the root zone; for foliar applications

may be combined with a labeled adjuvant for improved leaf adhesion or control in dense foliage.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 10 to 17 oz/A loopers, 13.5 to 20.5 oz/A fruitworm and hornworm; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 5 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection. Rates vary for different species.

deltamethrin (Delta Gold*): 1 to 2.4 oz/A for CL and THW, 1.5 to 2.4 for TFW; PHI 1d, REI 12h, Bee: H, Group 3A.

emamectin benzoate (Proclaim*): 2.4 to 4.8 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Apply when larvae are first observed.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A for looper and TFW; 2.9 to 5.8 oz/A for THW; PHI 1d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A for TFW and THW only; PHI 3d, REI 24, Bee: H, Group 3. May be combined at with DiPel DF for control of other caterpillars. See label for rates.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A for looper and hornworm, 1.02 to 1.54 oz/A for tomato fruitworm; PHI 5d, REI 24h, Bee: H, Group 3A.

indoxacarb (Avaunt): 2.5 to 3.5 oz/A; PHI 3d, REI 12h, Bee: H, Group 26. High rate for TFW.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A for CL and THW, 1.3 to 1.9 oz/A for TFW; PHI 5d, REI 24h, Bee: H, Group 3A.

malathion (Malathion 57EC): 1 to 2.5 pt/A; PHI 1d, REI 12h, Bee: H, Group 1B. TFW only.

methomyl (Lannate* LV): 1.5 to 3 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A.

methoxyfenozide (Intrepid 2F): 4 to 16 oz/A for CL and THW, 10 to 16 oz/A for TFW; PHI 1d, REI 4h, Bee: L, Group 18. For control of CL and THW and suppression of TFW. Use lower rates when plants are small or infestations are light.

novaluron (Rimon 0.83EC): 9 to 12 oz/A; PHI 1d, REI 12h, Bee: L, Group 16B.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Do not apply to varieties which produce fruit less than 1 inch in diameter, such as cherry and grape tomatoes.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OG}): 1 to 2 oz/A for control, 1.5 to 3 oz/A maintenance only; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant.

tbufenozide (Confirm 2F): 6 to 16 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Must be ingested. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations. Use of a spreader-binder adjuvant is recommended.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A for THW and TFW; 3.4 to 4.3 oz/A for CL; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Colorado Potato Beetle (*Leptinotarsa decemlineata*)

For more information, see Colorado potato beetle (CPB) in Potato and Eggplant sections. If possible, do not transplant tomatoes to fields previously in potato or eggplant. Trap cropping may be used by rotating tomatoes to opposite side of field from prior potato, eggplant or tomato planting, and seeding 2 rows of early potatoes between old and new plantings. Treat potatoes with effective insecticide to kill migrating beetles before they infest tomatoes. If foliar insecticides are needed on tomatoes, use only selective insecticides to preserve natural enemies and avoid secondary pest problems such as aphids. Although CPB may attack young transplants in the field, most varieties develop resistance within a few weeks of field setting.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; PHI 7d, REI 12h, Bee: H, Group 6. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

acetamiprid (Assail 30SG): 1.5 to 2.5 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

azadirachtin (Azatin O^{OG}): 4 to 16 oz/A foliar or drench, 4 to 16 oz/100 gal in greenhouses. When using lower rates, combine with adjuvant for improved spray coverage and translaminar uptake; PHI 0d, REI 4h, Bee: L, Group un. Insect growth regulator for small larvae.

Bacillus thuringiensis subsp. tenebrionis strain SA-10 (Trident^{OG}): 3 to 6 qt/A; PHI 0d, REI 4h, Bee: M, Group 11. Only use 3 qt/A rate when light populations of larvae of uniform age or size are present. Use of an adjuvant may improve efficacy, but avoid mixing with silicone-based surfactants. Do not apply while pollinators are actively visiting the treatment area.

Beauveria bassiana (Mycotrol ESO): 0.5 qt to 1 qt/A; PHI 0d, REI 4h, Bee: L, Group 22. Treat when populations are low and thoroughly cover foliage. Takes 7 to 10 days after the first spray to see control.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

chlorantraniliprole (Coragen): 3.5 to 7.5 oz/A; PHI 1d, REI 4h, Bee: L, Group 28. May be applied through drip irrigation or as a foliar spray. For soil applications, must be applied uniformly in the root zone; for foliar applications may be combined with a labeled adjuvant for improved leaf adhesion or control in dense foliage.

cyantraniliprole (Exirel): 7 to 13.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: H, Group 28. For drip chemigation, or soil injection applications.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

cyromazine (Trigard): 2.66 oz/A; PHI 0d, REI 12h, Bee: M, Group 17. Insect growth regulator for small larvae just after egg hatch. Suppression only.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress, or through drip. Do not apply to varieties with fruit that is less than 2", such as cherry or grape tomatoes.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

flupyradifurone (Sivanto): 10.5 to 14 oz/A; PHI 1d, REI 4h, Bee: L, Group 4D. Foliar applications only.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

novaluron (Rimon 0.83EC): 9 to 12 oz/A; PHI 1d, REI 12h, Bee: L, Group 16B.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 3d, REI 48h, Bee: H, Group 1A. Apply by ground or air when insects first appear.

permethrin (Pounce* 25WP): 3.2 to 12.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. Do not apply to varieties which produce fruit less than 1" in diameter, such as cherry and grape tomatoes.

petroleum oil (Suffoil X^{OC}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. Beetle larvae only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinetoram (Radiant SC): 5 to 10 oz/A; PHI 1d, REI 4h, Bee: M, Group 5.

spinosad (Entrust SC^{OC}): 3 to 6 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant.

thiamethoxam (Actara): 2 to 3 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticides used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting operations. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Cutworm, Black (*Agrotis ipsilon*) and Variegated (*Peridroma saucia*)

The most common species on tomatoes is the black cutworm, but occasionally the variegated cutworm can also be a problem. Black cutworms tend to do minor leaf feeding or cut seedling stems shortly after transplanting (see cutworms in the Pepper section for more information on black cutworm). Variegated cutworms occur later in the season and will feed on leaves, but will also chew shallow or deep holes in the fruit. Adults are night-flying reddish-brown moths, while the caterpillars are brownish-grey, with diamond-shaped marks along the back and light lines along the sides. They are up to 2" long. Moths from the South arrive in mid- to late summer. Some may also survive warm winters as pupae in the soil and feed on seedlings in the spring. The larvae hide under the soil surface, within the plant canopy or in fruit holes during the day and feed after dark. There are 2 generations per year. Moths can be monitored with a black light trap or with a yellow and white Unitrap from July through September. Scout fields weekly, checking at least 100 plants for fruit feeding. Spray tomatoes if 1% of the plants are infested with variegated cutworms. For best results, make application after dark. Thorough coverage of the upper and lower foliage is needed for good control. Parasitic flies, wasps and other general predators help reduce populations. Weedy plantings tend to suffer greater damage.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 5.2 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 12 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

***Burkholderia* spp. strain A396 cells and spent fermentation media (Venerate X^{OC}):** 1 to 8 qt/A; PHI 0d, REI 4h, Bee: M.

carbaryl (10% Sevin Granules): 20 lb/A; PHI 3d, REI 12h, Bee: H, Group 1A. Apply evenly over soil surface.

***Chromobacterium subsugae* strain PRAA4-1 (Grandevo^{OC}):** 1 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A Danitol 2.4EC + 0.25 to 2 lb/A Dipel DF; PHI 3d, REI 24, Bee: H, Group 3. Variegated cutworm only.

gamma-cyhalothrin (Declare*): 0.77 to 1.28 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

lambda-cyhalothrin (Warrior* II): 0.96 to 1.6 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

methomyl (Lannate* LV): 1.5 pt/A; PHI 1d, REI 48h, Bee: H, Group 1A. Variegated cutworm only.

spinosad (Seduce^{OC}): 20 to 44 lb/A or 0.5 to 1 lb/1000 sq ft.; PHI 1d, REI 4h, Bee: M, Group 5. Spread bait on soil around plants.

tebufenozide (Confirm 2F): 6 to 16 oz/A; PHI 7d, REI 4h, Bee: L, Group 18. Must be ingested. Use lower rate for early season applications to young, small plants. Begin applications when first signs of feeding damage appear. Use higher rate for later season applications and heavier infestations. Use of a spreader-binder adjuvant is recommended.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Flea Beetle, Potato (*Epitrix cucumeris*)

See the insect control section of Eggplant for information on flea beetles that attack potato and other solanaceous crops. Adults spend the winter under plant residue along tree lines or in the field. In the early spring, they feed on solanaceous weeds until they move to tomato or other solanaceous crops. Numerous tiny feeding shot holes can injure leaves and stunt young plants. Management practices include clean cultivation, crop rotation, removing or avoiding spring weed hosts, row covers, and spot treatments targeting young tomato plants along the field edges. Perimeter Trap Cropping: young tomato plants can be protected from flea beetles by planting Italian or Oriental eggplant around the tomato field. Full-size plants rarely require treatment for flea beetles. Most insecticides registered to control CPB, including spinosad, will control FB.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

beta-cyfluthrin (Baythroid* XL): 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A.

bifenthrin (Brigade* 2EC): 2.1 to 5.2 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

carbaryl (Sevin XLR Plus): 0.5 to 1 qt/A; PHI 3d, REI 12h, Bee: H, Group 1A.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting.

cyclaniliprole (Harvanta): 10.9 to 16.4 fl oz/A; PHI 1d, REI 4h, Bee: H, Group 28.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

dinotefuran (Venom): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Soil application may be as a band during bedding, in-furrow at seeding, transplant or post-seeding drench, sidedress or through drip. Do not apply to varieties with fruit that is less than 2", such as cherry or grape tomatoes.

esfenvalerate (Asana* XL): 5.8 to 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil; PHI 21d, REI 12h, Bee: H, Group 4A. Only soil applications allowed for flea beetle control.

kaolin (Surround WP^{OC}): 12.5 to 50 lb/A or 0.125 to 0.5 lb/gal; PHI 0d, REI 4h, Bee: L. Suppression and repellence only. May be applied to transplants prior to setting in field. Use on seedlings and young plants. Product residue may need to be washed off if applied after fruit set. White residue may be minimized if applications stop when fruit is 25% of its expected harvest size. Generally compatible as a tank mix with other insecticides.

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A.

petroleum oil (Suffoil X^{OC}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed. Beetle larvae only.

pyrethrin (PyGanic EC5.0^{OC}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

spinosad (Entrust SC^{OC}): 4 to 8 oz/A; PHI 1d, REI 4h, Bee: M, Group 5. Do not apply to seedlings for transplant. Suppression only.

thiamethoxam (Actara): 2 to 3 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray.

tolfenpyrad (Torac): 17 to 21 fl oz/A; PHI 1d, REI 12h, Bee: H, Group 21A.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

■ Slugs

Damage appears as shredded foliage or fruit holes. Look for silvery slime trails on leaves or turn over soil clods or debris to find slugs during daylight hours. Grow plants away from moist, shaded habitats, use clean cultivation, control weeds, hand pick/crush slugs or scatter baits on the ground near infested plants. See the Cabbage Section for more information on slugs.

iron phosphate (Sluggo: Snail and Slug Bait^{OC}): 20 to 44 lb/A; PHI 0d, REI 0h, Bee: L, Group 9B. Apply around perimeter, scatter around base of plants, or band down rows. Apply to moist soil in the evening.

metaldehyde (Deadline Bullets): 20 to 40 lb/A; REI 12h, Bee: L. Soil surface treatment broadcast pre-planting, or band treatment between rows after formation of edible parts. Apply to moist soil in the evening. Do not apply directly to or contaminate edible portions of plants.

■ Spotted Wing Drosophila (*Drosophila suzukii*)

Spotted Wing Drosophila SWD is an invasive pest that first arrived and spread throughout New England in 2011. It is primarily a pest of fruit crops, where the ability to oviposit in sound fruit (especially blueberry, raspberry, cherry, and peach) makes it a more serious pest than native fruit flies. SWD is deterred from laying eggs in sound tomato fruit by the strength of the tomato skin. However, where there are cracks

and other openings, eggs are laid and larvae build up in fruit, liquefying the fruit contents and leaving nothing but an empty skin. Thus the management of cracked fruit is key to preventing buildup of Spotted Wing populations in tomato and possible contamination of cracked tomato fruit and containers post-harvest. See Spotted Wing Drosophila in the insect control section of Greenhouse Tomato for more information on controlling SWD in the field and postharvest.

Follow Extension monitoring alerts or place traps on your own farm, to know when SWD is starting to build up in your area. Currently, there are no thresholds for use of insecticides to control SWD in tomato. Few insecticides are registered specifically for control of SWD on tomato. Consult Extension SWD materials for updates on efficacy of products labeled for tomato.

malathion (Malathion 57 EC): 2.5 pt/A or 1.5 to 2 pt/100 gal water; *PHI 1d, REI 12h, Bee: H, Group 1B.*

spinetoram (Radiant SC): 6 to 10 oz/A; *PHI 1d, REI 4h, Bee: M, Group 5.* Begin applications at first sign of adult activity. Due to the occurrence of multiple generations in a growing season, repeated applications may be required. Not for use in greenhouses.

■ **Stink Bugs, Brown (*Euschistus servus*) and Brown Marmorated (*Halyomorpha halys*)**

The brown stink bug is a native pest that feeds on blossoms, buds and fruit on a wide range of vegetables, fruits and weeds. Adults are plain brown or grayish-yellow, 11 to 15 mm long, and the shield-like shape typical of stink bugs is rounded at the 'shoulders'. Adults overwinter among plant debris and in weeds, and persist for 2 or more months in summer. Eggs are yellowish white laid in clusters of about 20. Nymphs are light colored, yellowish brown above and white to yellow underneath. There are 2 generations per year. Both adults and nymphs cause damage to tomato fruit, causing white star-like patches on the fruit skin with shallow injury to the flesh below the skin. Bugs migrate into fields from weedy borders, woods or brambles. Damage is worse in a dry season and is often limited to the edge of the field and border treatments are often adequate to manage this pest. High tunnel tomatoes may be affected. High weed pressure, reduced-tillage and increased use of cover crops may increase damage by providing hiding places within fields. Natural enemies in the field usually contain outbreaks if they are not disrupted by broad-spectrum insecticides. It is difficult to monitor by direct observation in tomato as it is reclusive, well-camouflaged and inconspicuous. Shake plants over sheet or tray to check for presence of bugs.

The brown marmorated stink bug (BMSB) was first documented in the US in PA in 2001 and since then has become a serious pest of fruit, vegetables and field crops in the mid-Atlantic region and a sporadic pest in the Hudson Valley region and southern New England. Its range is expanding northward into New England and its pest status is likely to increase. Adults have a shield-shaped body (a trait of most stink bugs), are about 3/4" (14 to 17 mm) long, 3/8" (8 mm) wide, and mottled or marbled grey-brown in color. The underside is white, sometimes with grey or black markings, and the legs are brown with faint white banding. One way to distinguish a BMSB from other stink bug species commonly found in New England is by the alternating dark

and light bands on the insect's last 2 antennae segments. The name stink bug refers to the scent glands located on the dorsal surface of the abdomen and the underside of the thorax. BMSB is also commonly confused with the Western Conifer Seed Bug; both invade homes in the fall to overwinter.

BMSB eggs are elliptical (1.6 x 1.3 mm), light yellow to yellow-red with minute spines forming fine lines. They are attached, side-by-side, to the underside of leaves in masses of 20 to 30 eggs. There are 5 nymphal instars (immature stages). Nymphs have deep red eyes, yellowish red abdomen in the first instar progressing to off-white with reddish spots in the fifth instar. The legs, head and thorax of nymphs are black. Adults overwinter and emerge (late April to mid-May), to mate and deposit eggs from May through August. They migrate into cropped areas from outside. There is likely one generation per year in New England, but research is indicating that two generations are occurring in mid-Atlantic states.

Fruits have been the most severely attacked (including apples, peaches, figs, mulberries, citrus fruits and persimmons). Other hosts include many ornamental plants, weeds and soybeans. Vegetable crops damaged by BMSB include sweet corn, tomatoes, lima beans and green peppers, and this list is likely to grow as the pest spreads into new areas. Feeding damage to fruits and vegetables includes scarring, cat-facing, spotting, and internal damage which reduce marketability.

Research on monitoring, thresholds and control methods is ongoing. Look for adults, eggs and nymphs and for damage. Insecticides labeled for stink bugs (without species indicated) may be used for Brown Marmorated Stink Bug; a few products have expanded labels to include BMSB. Look for additional information from state and regional Extension programs as more becomes known about this pest. In areas of New England where BMSB has yet to be reported, contact your state invasive species program to confirm identification of suspected BMSB samples.

beta-cyfluthrin (Baythroid* XL): 1.6 to 2.8 oz/A; *PHI 0d, REI 12h, Bee: H, Group 3A.*

bifenthrin (Brigade* 2EC): 2.1 to 5.2 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A.*

dinotefuran (Venom): 1 to 4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 4A.* Foliar applications only. For brown, consperse, green, and Southern green stink bugs only. Coverage is essential for adequate control.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A. May be combined with Belay for control of brown stink bug, but this combination should not be applied during bloom or if bees are actively foraging; *PHI 3d Danitol alone, PHI 21d Danitol + Belay, REI 24, Bee: H, Group 3.*

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

lambda-cyhalothrin (Warrior* II): 1.3 to 1.9 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A.*

methomyl (Lannate* LV): 1.5 to 3 pt/A; *PHI 1d, REI 48h, Bee: H, Group 1A.*

novaluron (Rimon 0.83EC): 12 oz/A; *PHI 1d, REI 12h, Bee: L, Group 16B.*

oxamyl (Vydate L): 1.5 to 3 pints/A foliar; *PHI 3d, REI 48h, Bee: H, Group 1A*. Apply once when insect populations are at threshold and repeat at 5-7 day intervals as needed. Apply by ground or air only in at least 20 gal of water/A by ground and in at least 5 gal/A by air. Supplemental label for BMSB expires 12/31/18. Confirm label allowances and rates after this date.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; *PHI 0d, REI 12h, Bee: M, Group 3A*.

thiamethoxam (Actara): 3 to 5.5 oz/A; *PHI 0d, REI 12h, Bee: H, Group 4A*.

zeta-cypermethrin (Mustang*): 2.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*. For green and brown stink bugs only. Use higher rate for brown stink bugs.

■ Tomato Russet Mite (*Aculops lycopersici*)

Surface feeding on stems produces a russeted or bronzed appearance, beginning at the soil line, which later moves up to leaves and fruit. Sulfur and other miticides are effective.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6*. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L*. Spray to wet all infested plant surfaces. Repeated applications may be necessary.

malathion (Malathion 57EC): 1 to 2.5 pt/A; *PHI 1d, REI 12h, Bee: H, Group 1B*.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L*.

neem oil (Trilogy^{OG}): 0.5 to 2% solution in 25 to 100 gal water/A; *PHI 0d, REI 4h, Bee: M, Group 18*. Avoid mid-day applications and ensure good coverage.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25*. Do not apply in midday sun or mix with copper, sulfur or oils.

spirotetramat (Movento): 4 to 5 oz/A; *PHI 1d, REI 24h, Bee: M, Group 23*. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfur (Microthiol Dispers^{OG}): 10 to 20 lb/A; *REI 24h, Bee: L, No IRAC classification*. Do not apply if temperature are expected to exceed 90°F during 3 days after application; may burn foliage under high temperatures.

■ Two-spotted Spider Mite (*Tetranychus urticae*)

For more information on TSSM see insect control section of Eggplant.

abamectin (Agri-Mek* SC): 1.75 to 3.5 oz/A; *PHI 7d, REI 12h, Bee: H, Group 6*. Must be mixed with a non-ionic wetting, spreading and/or penetrating spray adjuvant; do not use binder or sticker type adjuvant.

acequinocyl (Kanemite 15SC): 31 oz/A; *PHI 1d, REI 12h, Bee: L, Group 20B*. Do not use less than 100 gal water/A. Use of an adjuvant or surfactant is prohibited.

bifenazate (Acramite 50WS): 0.75 to 1 lb/A; *PHI 3d, REI 12h, Bee: L, Group 25*. Long residual; not systemic, ensure complete coverage of upper and lower leaf surfaces and fruit.

bifenthrin (Brigade* 2EC): 5.12 to 6.4 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*.

fenpropathrin (Danitol* 2.4EC): 10.7 oz/A; *PHI 3d, REI 24, Bee: H, Group 3*. Treat when mite populations are just beginning to build, less than 5 motiles per leaf.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; *PHI 5d, REI 24h, Bee: H, Group 3A*. Suppression only.

fenpropathrin (Danitol* 2.4EC): 10.66 oz/A; *PHI 3d, REI 24, Bee: H, Group 3*.

fenpyroximate (Portal XLO): 2 pt/A; *PHI 1d, REI 12h, Bee: L, Group 21A*.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; *PHI 0d, REI 12h, Bee: L*. Spray to wet all infested plant surfaces. Repeated applications may be necessary.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); *PHI 0d, REI 0h, Bee: L*.

neem oil (Trilogy^{OG}): 0.5 to 2% solution in 25 to 100 gal water/A; *PHI 0d, REI 4h, Bee: M, Group 18*. Avoid mid-day applications and ensure good coverage.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; *PHI 0d, REI 4h, Bee: L*. Apply as needed.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; *REI 12h, Bee: L, Group 25*. Do not apply in midday sun or mix with copper, sulfur or oils.

soybean oil (Golden Pest Spray Oil^{OG}): 2 gal/10 to 80 gal water/A; *REI 4h, Bee: L, Group 25*. Apply once a week beginning when mites first appear.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; *PHI 1d, REI 12h, Bee: M, Group 23*. Effective on all developmental stages, but juvenile stages more susceptible than adults.

sulfur (Microthiol Dispers^{OG}): 5 to 20 lb/A; *REI 24h, Bee: L, No IRAC classification*.

tolfenpyrad (Torac): 14 to 21 fl oz/A; *PHI 1d, REI 12h, Bee: H, Group 21A*.

■ Whitefly, greenhouse (*Trialeurodes vaporariorum*) and sweet potato (*Bemisia tabaci*)

Whiteflies found in the outdoor vegetable crops in New England are most commonly greenhouse whitefly (*Trialeurodes vaporariorum*) or, less commonly, sweet potato whitefly B-biotype (*Bemisia tabaci*). For more information on biology and management, see whiteflies in the insect control section of Greenhouse Tomato. Whitefly outbreaks in field tomatoes and other field crops are not common in New England. Both species winter-kill but may be introduced on infested transplants that are moved from the greenhouse to the field. Manage populations in the greenhouse using biological controls or insecticides (see Insect and Mite Management in the Vegetable Transplant

section for more on managing whitefly on transplants in the greenhouse). Natural enemies in the field may contain outbreaks if they are not disrupted by broad-spectrum insecticides. Row covers over transplants may protect whiteflies from natural enemies, allowing populations to build. If whitefly populations reach high levels, damage appears as yellowing, spots, leaf drop, plant wilting or stunting, and may result in problems with honeydew and sooty mold or viruses. Most feeding occurs on lower leaf surfaces, so systemic insecticides are often more effective than contact insecticides. Practice resistance management by alternating between insecticide groups to preserve the effective life of products.

acetamiprid (Assail 30SG): 2.5 to 4 oz/A; PHI 7d, REI 12h, Bee: M, Group 4A.

afidopyropen (Sefina): 14 fl oz/A; PHI 0d, REI 12h, Bee: L, Group 9D.

alpha-cypermethrin (Fastac* EC): 2.2 to 3.8 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Suppression only.

beta-cyfluthrin (Baythroid* XL): 2.8 oz/A; PHI 0d, REI 12h, Bee: H, Group 3A. For suppression of adult whiteflies only.

bifenthrin (Brigade* 2EC): 2.1 to 5.2 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

buprofezin & flubendiamide (Vetica): 14 to 17 oz/A; PHI 1d, REI 12h, Bee: L, Groups 16 & 28.

Chenopodium extract (Requiem EC): 2 to 3 qts/A; PHI 0d, REI 4h, Bee: L. Silverleaf whitefly only. Apply before pests reach damaging levels.

Chromobacterium subsugae strain PRAA4-1 (Grandevo^{OG}): 2 to 3 lb/A; PHI 0d, REI 4h, Bee: M.

cyantraniliprole (Exirel): 13.5 to 20.5 oz/A; PHI 1d, REI 12h, Bee: H, Group 28.

cyantraniliprole (Verimark): 6.75 to 13.5 oz/A at planting, 6.75 to 10 oz/A chemigation; PHI 1d, REI 4h, Bee: H, Group 28. For soil applications at planting, drip chemigation, or soil injection.

deltamethrin (Delta Gold*): 1.5 to 2.4 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A. Suppression only.

dinotefuran (Safari): 1 to 4 oz/A foliar or 5 to 7.5 oz/A soil; REI 12h, Bee: H, Group 4A. For transplants while in greenhouse. Not for use on greenhouse or field crops.

dinotefuran (Venom): 7 to 14 dry oz/A foliar or 18 to 21 dry oz/A soil; PHI 1d foliar, PHI 21d soil, REI 12h, Bee: H, Group 4A. Do not apply to varieties with fruit that is less than 2", such as cherry or grape tomatoes.

esfenvalerate (Asana* XL): 9.6 oz/A; PHI 1d, REI 12h, Bee: H, Group 3A.

fenpropathrin (Danitol* 2.4EC): 7 to 10.66 oz/A Danitol 2.4EC + 3-4 oz/A Belay; PHI 21d, REI 24, Bee: H, Group 3. Do not apply during bloom or if bees are actively foraging.

fenpyroximate (Portal XLO): 2 pt/A; PHI 1d, REI 12h, Bee: L, Group 21A.

flonicamid (Beleaf 50SG): 2.8 to 4.28 oz/A; PHI 0d, REI 12, Bee: L, Group 9C. Begin applications before populations begin to build, and before damage is evident. Use higher rate for building populations or dense foliage. Suppression only.

flupyradifurone (Sivanto): 10.5 to 14 oz/A foliar, 21 to 28 oz/A soil; PHI 1d foliar, PHI 45d soil, REI 4h, Bee: L, Group 4D.

gamma-cyhalothrin (Declare*): 1.02 to 1.54 oz/A; PHI 5d, REI 24h, Bee: H, Group 3A. Suppression only.

imidacloprid (Admire Pro): 7 to 10.5 oz/A soil, 1.3 to 2.2 oz/A foliar, 0.44 oz/10,000 plants on seedling transplants in greenhouse; PHI 21d soil, PHI 0d foliar, REI 12h, Bee: H, Group 4A. Planthouse applications only provide short-term protection; an additional field application must be made within 2 weeks following transplanting to provide continuous protection.

insecticidal soap (M-Pede^{OG}): 1.25 to 2.5 oz/gal water; PHI 0d, REI 12h, Bee: L. Spray to wet all infested plant surfaces. For enhanced and residual control apply with a companion labeled insecticide.

Metarhizium anisopliae Strain F52 (Met 52 EC): 40 to 80 oz/100 gal (drench), 8 to 64 oz/A (foliar); PHI 0d, REI 0h, Bee: L.

oxamyl (Vydate* L): 2 to 4 pt/A; PHI 3d, REI 48h, Bee: H, Group 1A. Apply by ground or air when insects first appear. Suppression only.

petroleum oil (Suffoil X^{OG}): 1 to 2 gal/100 gal water; PHI 0d, REI 4h, Bee: L. Apply as needed.

pymetrozine (Fulfill): 2.75 oz/A; PHI 0d, REI 12h, Bee: L, Group 9A. Suppression only. Apply when whiteflies first appear.

pyrethrin (PyGanic EC5.0^{OG}): 4.5 to 17 oz/A; 0.25 to 0.50 oz/gal, 3 gal/1000 sq ft in greenhouse for backpack sprayers; PHI 0d, REI 12h, Bee: M, Group 3A.

pyriproxyfen (Knack): 8 to 10 fl oz/A; PHI 14d, REI 24h, Bee: L, Group 7. For control of eggs and immature stages; does not control adults, but hatching of eggs laid by treated adults may be suppressed. Apply when threshold levels are reached. Translaminar.

sodium tetraborohydrate decahydrate (Prev-AM): 50 oz/100 gal; REI 12h, Bee: L, Group 25. Do not apply in midday sun or mix with copper, sulfur or oils.

spiromesifen (Oberon 2SC): 7 to 8.5 oz/A; PHI 1d, REI 12h, Bee: M, Group 23. Most effective on immature stages.

spirotetramat (Movento): 4 to 5 oz/A; PHI 1d, REI 24h, Bee: M, Group 23. Must be tank-mixed with a spray adjuvant with spreading and penetrating properties to maximize leaf uptake and systemicity; don't use sticker adjuvants. Controls immature stages; may also reduce adult fertility.

sulfoxaflor (Closer SC): 1.5 to 2 oz/A. Do not apply until after petal fall; PHI 1d, REI 12h, Bee: H, Group 4C.

thiamethoxam (Actara): 3 to 5.5 oz/A; PHI 0d, REI 12h, Bee: H, Group 4A.

thiamethoxam (Platinum): 5 to 11 oz/A; PHI 30d, REI 12h, Bee: H, Group 4A. Systemic insecticide used as an in-furrow, banded, drench, or drip irrigation application to the seedling root zone during or after transplanting or shanked into root zone after transplanting or establishment. DO NOT apply as a foliar spray.

zeta-cypermethrin (Mustang*): 3.4 to 4.3 oz/A; *PHI 1d, REI 12h, Bee: H, Group 3A*. Suppression only.

WEED CONTROL

NOTE: For the herbicides listed below, one product trade name and formulation is provided for each active ingredient as an example of rate, preharvest interval (PHI), restricted entry interval (REI), and special instructions. In many cases, there are other products available with the same active ingredient. However, not all products with the same active ingredient are registered for use in a crop. See Herbicides Alphabetically Listed by Active Ingredient (page 105) and Tables 27 and 28 (pages 108-109).

■ Stale Seedbed

See Stale Seedbed Technique, page 107.

glyphosate (Roundup Power Max): *REI 12h, Group 9*.

paraquat (Gramoxone SL 2.0*): restricted use. *REI 12h, Group 22*. Use 2-4 pts/A.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17*. Use a 3-10% solution (3 to 10 gallons per 100 gallons).

■ Herbicides Used Preemergence to Weeds

DCPA (Dacthal 75WP): *REI 12h, Group 3*. Crop should be well established before use. Apply 4-6 weeks after transplanting or on direct seeded plants at 4-6 inches in height. Will not control emerged weeds. If weeds have emerged, the crop should be cultivated or weeded prior to application. Apply 6 to 14 lb/A. See label to select rate based on target weeds and soil texture.

napropamide (Devrinol 2-XT): *REI 12h, Group 15*. Apply 2 to 4 qt/A before transplanting, to weed-free soil surface. Use the lower rate on light soil (coarse-textured - sandy) and the higher rate on heavy soil (fine textured - clay). Incorporate thoroughly with irrigation if adequate rainfall does not occur within 24 hours of application. Can be used under plastic mulch.

pendimethalin (Prowl H₂O): *PHI 21d, 24 hr REI, Group 3*. Apply 1 to 3 pt/A, either as preplant incorporated or to the soil surface PRIOR to transplanting. If applied to the soil surface, excessive treated soil falling into the transplant hole may delay crop growth. Can be used under plastic mulch. Can also be applied as a post-directed spray on the soil at the base of the plant, beneath plants, and between rows. Avoid direct contact with foliage or stems or injury will occur. Apply before weed germination. Emerged weeds will not be controlled.

s-metolachlor (Dual Magnum): *PHI 90d for applications greater than 1.33 pt/A, PHI 30d for applications 1.33 pt/A or less, REI 12h, Group 15*. Used to control annual grasses, yellow nutsedge, nightshade species, galinsoga, and certain other broadleaf weeds. Apply Dual Magnum before weeds germinate; will not control emerged weeds. Apply Dual Magnum, either preplant incorporated or preplant prior to transplanting tomatoes. If the applied preplant, keep soil disturbance to a minimum during the transplanting. Application may also be made as a directed to spray to tomatoes after the first settling rain/irrigation after transplanting. When an application is made post-directed, apply in a minimum of 20 gallons of water per acre and minimize contact with tomato plants. If using plastic

mulch, apply Dual Magnum preplant non-incorporated to the top of the pressed bed, as the last step prior to laying plastic. Dual Magnum may also be used to treat row-middles in bedded tomatoes, as long as the total amount of Dual Magnum does not exceed the maximum allowed soil type.

- **On coarse soils:** 1.0-1.33 pt/A if organic matter content is less than 3% or 1.33 pt/A if organic matter is 3% or greater.
- **On medium soils:** apply 1.33-1.67 pt/A.
- **On fine soils:** apply 1.33-1.67 pt/A if organic matter content is less than 3% or 1.67-2.0 pt/A if organic matter content is 3% or greater.

trifluralin (Treflan HFP): *REI 12h, Group 3*. For transplant tomatoes, apply 1 to 2 pt/A and incorporate before transplanting or apply post-plant as a directed spray to the soil between the rows and beneath plants and incorporate. Select rate based on soil texture; see label for details. Must be incorporated into the top 2 to 3 inches of the final seedbed within 24 hours of application. Disc twice after spraying for satisfactory incorporation. See label for info on incorporation recommendations based on different equipment and single pass incorporation. Little or no control of ragweed, galinsoga, mustard or nutsedge.

■ Herbicides Used Pre- and Postemergence to Weeds

halosulfuron (Sanda): *PHI 30d, REI 12h, Group 2*. Will provide both preemergence and postemergence control of many weed species. The potential for crop injury is greatest when Sandea is used over transplants grown on bare ground. See the label for other precautions and a list of weeds controlled. Do not apply more than 2 applications or 2 oz/A per 12 month period (Includes applications to the crop and to row middle/furrows).

- **Direct seeded tomatoes:** Apply 0.5 to 1 oz/A over the top once tomatoes have reached the 4 leaf stage through 30 days prior to harvest. Applications following bloom could cause some bloom drop under certain environmental conditions. Apply as a directed spray or with crop shield when these conditions are present.
- **Transplanted tomatoes, Pre-transplant:** Apply 0.5 to 1 oz/A as a preplant application to bare ground or if using plastic mulch, following final bed shaping and just prior to the installation of the plastic mulch. Tomatoes can be transplanted into treated area 7 days after the application unless local conditions demonstrate safety at an earlier interval. Use lower rate on lighter textured soils with low organic matter. Care should be taken to limit the movement of treated surface soil into the transplant hole during the transplant process, or crop injury can occur.
- **Transplanted tomatoes, Post-transplant:** Apply 0.5 to 1 oz/A over the top, post directed, or with crop shields to tomato transplants that are established, actively growing and a minimum of 14 days after transplanting unless local conditions demonstrate safety at an earlier interval. Applications following bloom could cause some bloom drop under certain environmental conditions. Application as a directed spray or with crop shields should be considered when conditions are present.

- **Row Middle/Furrow Applications:** Apply between rows for the control of nutsedge and listed broadleaf weeds. Avoid contact of the herbicide with the planted crop. If plastic is used on the planted row, adjust equipment to keep the application off the plastic. Reduce rate and spray volume in proportion to area actually sprayed.
- **Split Applications for Nutsedge:** To maximize control of nutsedge, it may be necessary to use a postemergence spot application to those areas where the nutsedge has germinated or regrown.

Pre-transplant followed by postemergence for nutsedge control:

For these situations, use a spot treatment method treating only those areas of emerged nutsedge. Application rate should not exceed 0.75 oz/A in these areas. Use a water volume that will allow for good coverage of the weeds.

Postemergence followed by postemergence for nutsedge control: Allow a minimum of 21 days between applications. Application rate should not exceed 1 oz product per treated acre in these areas.

rimsulfuron (Matrix): *PHI 60d, 4 hr REI, Group 2.* Can be used pre- and postemergence. Multiple applications permitted, not to exceed 4 oz/A per year. Can be tank mixed with several herbicides. See label for details.

- **Preemergence:** Apply 2 to 4 oz/A before transplanting. Activation by a single rainfall or irrigation event (1/2" to 1") is needed within 5 days of application. If rainfall or sprinkler activation cannot be managed, waiting for weeds to emerge and applying postemergence would result in better weed control. If weeds are present at application, add a nonionic surfactant at 1 to 2 pt/100 gal water. Weak on lambsquarters. If weeds are present at application, the addition of a spray adjuvant may improve weed control.
- **Postemergence:** Apply 1 to 2 oz/A to young, actively growing weeds after crop emergence. Weeds less than 1" in height or diameter at application are most easily controlled. A rainfall or irrigation event (1/3" to 1") no sooner than 4 hours, but not more than 5 days after application, will activate Matrix in the soil and help provide control of subsequent flushes of annual weeds. Use a surfactant at a minimum rate of 0.25% V/V (crop oil concentrate, methylated seed oils, nitrogen fertilizer solution or nonionic surfactant). If using multiple postemergence applications, optimum control is seen when the first application is made to small actively growing weeds, followed by a second application 7 to 14 days later.

metribuzin (Metribuzin 75): *PHI 7d, REI 12h, Group 5.* Do not exceed 1.3 lb/A total per season. Allow at least 14 days between applications. Do not apply within 3 days after periods of cool, wet or cloudy weather, or crop injury will occur.

- **Preplant incorporated (transplanted tomatoes):** Apply 0.3 to 0.6 lb/A in at least 10 gallons of water per acre as a broadcast spray to the soil surface immediately before transplanting. Incorporate to a depth of 2 to 4".
- **Postemergence:** One or more applications may be applied/use season (not to exceed 1.3 lb/A per year). Allow at least 14 days between applications or severe crop injury may occur. For transplanted tomatoes, do not apply until

transplants have recovered from transplant shock and new growth is evident. Do not apply to tomatoes within 24 hours of application of other pesticides.

Postemergence Broadcast Spray: Apply 0.3 to 0.6 lb/A in at least 20 gallons of water per acre as a broadcast spray over the tops of tomato plants.

Postemergence Directed Spray: This method of treatment should be used for use in fields with a history of severe weed pressure or in fields infested with hard-to-control weeds. Apply 0.6 to 1.3 lb/A in at least 20 gallons of water per acre as a directed spray. Avoid contacting tomato foliage with spray.

■ **Herbicides Used Postemergence to Weeds**

carfentrazone (Aim EC): *REI 12h, Group 14.* Aim is a burndown herbicide and will injure any foliage it comes into contact with. Apply Aim to areas between rows only with hooded sprayers to control emerged weeds, including crops grown on mulch or plastic. Prevent any spray from contacting the crop, or injury will occur. For best results, make application to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across. Good coverage is essential for good control. Apply up to 2 oz/A per application, and do not exceed a total of 6.1 oz/ per season.

clethodim (Select Max): *PHI 20d, 24hr REI, Group 1.* Will control grass weeds only. Apply to actively growing grasses. See label for rate selection. Multiple applications permitted of 9 to 32 oz/A per application, minimum 14-days between applications, not to exceed 64 oz/A per year. Add 0.25% v:v nonionic surfactant (1 qt per 100 gal of spray). Can also be used as a spot-spray by mixing 1/3-2/3% (0.44 to 0.85 oz per gallon) Select Max and 0.25% v:v nonionic surfactant (0.33 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

paraquat (Gramoxone SL 2.0*): *REI 12h, Group 22.* For use between rows after crop establishment. Apply up to 2 pt/A as a directed and shielded spray to emerged weeds between rows when weeds are succulent and weed growth is less than 6". Maximum 3 applications per year. Use precision directed spray application equipment adjusted to prevent spray contact with crop plants. Crop contact by the spray will cause severe injury or death. Do not exceed 30 psi nozzle pressure or spray under conditions which may cause excessive drift.

pelargonic acid (Scythe): *PHI 1d, REI 12h, Group 17.* Use a 3-10% solution (3 to 10 gallons per 100 gallons). Use a 3 to 5% solution for annual weeds, a 5 to 7% solution for biennial and perennial weeds, and 7 to 10% solution for maximum burndown. Delivery rate for boom applications should be 75 to 200 gals of spray solution per acre; complete coverage of weed foliage is essential. Use a DIRECTED/ SHIELDED SPRAY; contact with crop will cause injury. For hand-held equipment, spray to completely wet all weed foliage but not to the point of runoff. Repeat applications as necessary. Tank mixes are allowed with this product. See label for complete details.

sethoxydim (Poast): *PHI 20d, REI 12h, Group 1.* Controls grass weeds only. Apply to actively growing grasses (see product label for susceptible stage). Maximum 1.5 pt/A per application, minimum 14-days between applications. Do not exceed 4.5 pt/A per year. Use with crop oil concentrate (2.0

pt/A) or methylated seed oil (1.5 pt/A). Note that crop oil can cause injury under hot and humid conditions. Can also be used as a spot-spray by mixing 1-1.5% (1.3 to 1.9 oz per gallon) Poast and 1% v:v crop oil concentrate (1.3 oz per gallon). Spray to wet, but do not allow runoff of spray solution.

PHYSIOLOGICAL DISORDERS

■ Blossom End Rot

A physiological disorder associated with insufficient uptake and translocation of calcium to the fruit. For control, ensure adequate moisture and calcium in the soil. It is essential to maintain uniform soil moisture throughout the season. Do not permit plants to wilt during hot days. Do not use urea or ammonium sources of N for sidedressing or fertigation because these forms of nitrogen inhibit calcium uptake. Avoid injuring roots.

■ Blotchy Ripening and Greywall

Blotchy ripening is most often found in greenhouses and damage to fruit may be significant. It can also be encountered in the field in fresh-market and processing tomato crops. This poorly understood physiological disorder seems to be a consequence of any environmental stress that slows the

growth of the plant, particularly sudden stress that occurs at some point early in fruit development. The cause of this physiological disorder and its relationship to “grey wall” is not well understood. Blotchy ripening has been linked to potassium and/boron deficiency and to high nitrogen levels, which promote excessive growth. This syndrome has sometimes been linked to infection by Tomato Mosaic Virus, but this does not seem to be the definitive cause. Weather plays a role in the development of blotchy ripening; the disorder is more prevalent when temperatures are very high. Affected fruit ripen unevenly, with hard, gray to yellow patches. The patches do not turn red, but remain gray or turn yellow. When fruit are cut, the vascular tissues may appear brown and rotted. Growers should provide balanced fertilization and, in greenhouses, avoid excessively high temperatures, if possible. Cultivars vary in susceptibility to greywall. Avoid those varieties which show excessive symptoms. Improper temperatures, moisture levels, cloudiness or nutrition can contribute to this problem. Avoid injury to roots. Do not sidedress with urea or ammonium sources of nitrogen.

■ Fruit Cracking

See Physiological Disorders in Greenhouse Tomato section.

Risk Management and Crop Insurance

United States Department of Agriculture Risk Management Agency July 1, 2019

The USDA Risk Management Agency (RMA) helps farmers manage their business risks through effective, market-based risk management solutions. As part of its mission, RMA provides Federal crop insurance to producers through the Federal Crop Insurance Corporation (FCIC). While private-sector insurance companies sell and service the policies, RMA approves and supports products, develops and approves premium rates, administers premium and expense subsidies, and reinsures the private companies. RMA also supports educational and outreach programs on managing farming risks.

Crop and revenue insurance are important risk management tools available to America's farmers, however, the New England states are considered "underserved states" by RMA because insurance enrollment by farmers in this region continues to be less than the national average. Since its creation in 1996, RMA, in collaboration with New England Land Grant Universities, State Departments of Agriculture and private industry, have been reaching out to growers and agricultural professionals to make them aware of the opportunities, as well as the limitations, of crop insurance policies. The results of these efforts have steadily improved farmer understanding and use of crop insurance in the region.

Since 2000, existing insurance policies have been significantly modified and new products introduced to better suit the unique needs of the region's growers. Federal Crop Insurance is available in New England in select states and select counties for farmers who grow sweet corn, potatoes and green peas when production losses occur due to adverse weather and other insured causes. For other noninsured vegetable crops, a grower may submit a written request for crop insurance coverage by completing and submitting appropriate forms through their crop insurance agent. Alternatively, protection for these other noninsured vegetable crops is available from the USDA - Farm Service Agency (FSA) through the Noninsured Crop Disaster Assistance Program (NAP). NAP coverage provides a catastrophic level option, which allows a producer to protect 50% of their historical yield at 55% of the average market price. NAP provides a "Buy-Up" coverage option, allowing farmers to insure up to 65% of their historical yield at 100% of the average market price. Vegetable producers interested in learning more about NAP, coverage options and anticipated costs of NAP coverage are encouraged to contact the FSA Office that serves their farming operation.

For an overall coverage option, Whole-Farm Revenue Protection (WFRP) provides coverage for all crops grown on a farm under one policy by insuring farm revenue losses due to unavoidable natural causes. WFRP coverage was first available for the 2015 season, replacing the Adjusted Gross Revenue (AGR) pilot program.

For more information about RMA, crop insurance policies and risk management strategies go to the RMA website at <http://www.rma.usda.gov/>. Specific policy information for each New England State can be found by clicking on the "Commodities" Tab on the RMA home page and then looking up the commodity and selecting the appropriate State.

You can locate a crop insurance agent online at: <http://www.rma.usda.gov/en/information-Tools/Agent-Locator-Page>. Keep in mind that crop insurance agents are not employees of RMA or FCIC, rather, they or their company contract with USDA to sell and service Federal crop insurance policies. More importantly, crop insurance agents are the professionals with on-the-ground experience and knowledge of what works and what doesn't for a particular situation. Spending time with an agent can help you decide if and how crop or revenue insurance might best fit your needs.

Is now the time to be covered by Federal crop insurance? Let's consider a few important factors which may help you decide:

- The volatility of farm income has increased significantly over the past few decades. Environmental and economic conditions have led to greater variability and uncertainty in farm sales and profits.
- There has been a trend away from Congress funding the common "disaster based programs" that have sometimes provided "free insurance" in areas where losses are catastrophic. Congress is under increasing pressure to encourage growers to share in the management of farming risks.
- Lenders see federal crop insurance as a means to reduce their risk exposure, improving a farmer's eligibility, as well as an opportunity, to secure better loan terms.
- Federal crop and whole farm revenue insurance can be a very good value if the coverage fits your needs. Due to significant ongoing subsidies from the federal government, farmers do not pay for the full cost of coverage. For the Fresh Market Sweet Corn policy, the federal government subsidizes from 55 to 100 percent of the premium cost depending on the coverage level selected by the grower. For the Potatoes and Green Peas policies, subsidies range from 55 to 67 percent.

Federal crop and revenue insurance policies, along with NAP coverage for noninsured crops is your primary protection if a natural disaster were to damage your crops. If coverage makes sense for your upcoming growing season, find out more information as soon as possible. Keep in mind that many applications must be completed in the fall or winter prior to planting.

This information is provided by The United States Department of Agriculture's Risk Management Agency (RMA), in cooperation with the Extension programs of the New England states. Developed by Michael Sciabarrasi, Extension Professor (Retired), UNH Cooperative Extension and updated by Paul Russell and Thomas Smiarowski, Agricultural Risk Management Educators, UMass Extension.

THE BIG FIVE RISKS FACED BY FARMERS

As you think about managing risk to stabilize farm income, there are five basic sources of agricultural risk that you should address: Production, marketing, financial, legal, and human resource risks. Various tools and strategies can be used to manage each of these risks.

1) Production Risks

Production risks relate to the possibility that your yield or output levels will be lower than projected. Major sources of production risks arise from adverse weather conditions such as drought, freezes, or excessive rainfall at harvest or planting. Production risks may also result from damage due to insect pests and disease despite control measures employed, and from failure of equipment and machinery such as an irrigation pump.

Strategies to manage production risks include:

- Follow recommended production practices.
- Diversify enterprises by growing different crop varieties and completely new crops.
- Expand production through more intensive growing practices or by planting more acreage.
- Purchase federal crop insurance coverage to stabilize income during times of loss and purchase NAP coverage for noninsured crops.
- Adopt risk mitigating practices such as drip irrigation, tile drainage, trap crops or resistant varieties.
- Consider site selection - use fields less susceptible to frost or pests and rotate crops.
- Maintain equipment and keep facilities in good working condition.

2) Marketing Risks

Marketing risks relate to the possibility that you will lose the market for your products or that the price received will be less than expected. Lower sales and prices due to increased numbers of competing growers or changing consumer preferences are common sources of marketing risk. Marketing risks can also arise from loss of market access due to a wholesale buyer or processor relocating or closing, or if a product fails to meet market standards or packaging requirements.

Strategies to manage marketing risks include:

- Develop a marketing plan with realistic sales forecasts and target prices.
- Form or join a marketing cooperative to enhance prices and guarantee a market.
- Increase direct marketing efforts to capture a higher price.
- Market through multiple channels or outlets to reduce reliance on a single market.
- Enter into sales or price contracts with buyers.
- Spread harvest and sales over the season by scheduling planting and considering storage.
- Conduct essential market research - understand your customers' needs and preferences.
- Purchase Whole-Farm Revenue Protection to cover unexpected decline of market prices during the growing year.

3) Financial Risks

Financial risks relate to not having sufficient cash to meet expected obligations, generating lower than expected profits, and losing equity in the farm. Sources of financial risk commonly result from production and marketing risks described earlier. In addition, financial risks may also be caused by increased input costs, higher interest rates, excessive borrowing, higher cash demand for family needs, lack of adequate cash or credit reserves, and unfavorable changes in exchange rates.

Strategies to manage financial risks include:

- Develop a strategic business plan.
- Monitor financial ratios and enterprise benchmarks.
- Control key farm expenses - consider other suppliers and alternative inputs.
- Conduct a trend analysis to assess change in farm profits and owner's equity over time.
- Consider purchasing Whole-Farm Revenue Protection to provide a safety net in poor earning years.
- Communicate and renegotiate agreements with suppliers and loan terms with lenders.
- Consider leasing and rental options rather than purchasing machinery, equipment or land.
- Evaluate the possibility of expanding or contracting different enterprises.
- Control or defer unnecessary family and household expenditures.
- Find off-farm employment for a family member, preferably a job with benefits such health insurance, group life insurance, and a retirement program.
- Use non-farm investments such as IRAs or mutual funds to diversify your asset portfolio.

4) Legal and Environmental Risks

In part, legal risks relate to fulfilling business agreements and contracts. Failure to meet these agreements often carry a high cost. Another major source of legal risk is tort liability—causing injury to another person or property due to negligence. Lastly, legal risk is closely related to environmental liability and concerns about water quality, erosion and pesticide use.

Strategies to manage legal risks include:

- Review business insurance policies and carry sufficient liability coverage.
- Choose a different business legal structure—as an example, a sole proprietorship is not always best.
- Understand business contracts and agreements—ask questions if you are unsure.
- Develop good relationships with neighbors and address their concerns.
- Use good agricultural practices to limit environmental risk.
- Know and follow state and federal regulations related to your farming operation.

5) Human Resource Management Risks

Human resource risks pertain to risks associated with individuals and their relationships to each other. These relationships include those with family members, as well as farm employees and customers. Key sources of human resource risk arise from one of the “three D’s”—divorce, death, or disability. The impact of any of these events can be devastating to a farm. Human resource risks also include the negative impacts arising from a lack of people management skills and poor communications.

Strategies to manage human resource risks:

- Develop and practice good “people skills” with family members, as well as employees.
- Evaluate alternative sources of labor.
- Provide adequate training for employees—formalized programs may help your safety record and improve performance.
- Communicate with employees and family members.
- Recognize and reward good performance.
- Review wills, trusts, and powers of attorney.
- Initiate estate transfer and business succession planning.
- Consider health and life insurance needs.

Managing risk starts with identifying the most crucial risks you face; understanding the potential impacts and likelihood of undesirable outcomes; and, identifying and taking possible steps to mitigate or lessen the impacts. It’s unlikely any one person understands all the areas of risk faced by a family farm. If you don’t know the answer or find it difficult to initiate risk management planning on your own, get assistance from Cooperative Extension, USDA, attorneys, bankers, insurance agents, and other service providers.

Written by Michael Sciabarrasi, Extension Professor (Retired), Agricultural Business Management, UNH Cooperative Extension.

FEDERAL CROP INSURANCE POLICIES

Federal Crop Insurance Policies for Vegetable Crops in New England*

Connecticut	Fresh Market Sweet Corn, Potatoes
Maine	Fresh Market Sweet Corn, Green Peas, Potatoes
Massachusetts	Fresh Market Sweet Corn, Potatoes
New Hampshire	Fresh Market Sweet Corn
Rhode Island	Fresh Market Sweet Corn, Potatoes
Vermont	Fresh Market Sweet Corn

*Not all counties in a state offer the policies listed above, check with a Federal Crop Insurance agent to see if a crop is covered in your county.

Fresh Market Sweet Corn

Available in Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

Acreage planted to sweet corn to be harvested and sold as fresh market sweet corn is insurable for irrigated and

non-irrigated acreage. To be insured, the producer must have grown sweet corn for commercial sale or participated in managing a sweet corn farming operation in at least one of the three previous crop years.

Exclusion: Sweet corn inter-planted with another crop or in established grasses or legumes is not insurable. (However, using approved cover crop practices may not affect insurability.)

■ Causes of Loss

This policy protects against crop loss due to drought, excess rain, excess wind, freeze, hail, failure of irrigation water supply, fire, and wildlife.

NOTE: This policy does not cover any loss of production due to disease or insect infestation, unless effective control measures do not exist for such infestation. This policy also does not cover failure to market the sweet corn, unless such failure is due to actual physical damage caused by an insured cause of loss that occurs during the insurance period.

■ Insurance Period

Coverage begins when the sweet corn is planted. Coverage ends the earliest of (1) total destruction of the crop, (2) harvest of the acreage insured, (3) abandonment of the crop, (4) final adjustment of a loss, or (5) end of insurance date (check with your crop insurance agent for the date for your state and county).

■ Reporting Requirements

A report of all insured acreage of fresh market sweet corn in the county must be submitted to your crop insurance agent by July 15.

If a loss occurs, you must notify your crop insurance agent within 72 hours of your initial discovery of damage (but not later than 15 days after end of insurance period).

■ Definitions

Allowable Cost: An amount not to exceed \$4.15 per container for harvesting and marketing costs (e.g., picking, hauling, packing, shipping, etc.) is subtracted from the average price received to determine value of sold production.

Container: Fifty ears of fresh sweet corn.

Minimum Value: A minimum value of \$6.50 per container will be used to determine value of any sold production valued at less than \$6.50 after subtracting allowable cost.

Reference Maximum Dollar Amount: The value per acre established for the state. Amounts vary by state, so check with a crop insurance agent to determine the Reference Maximum Dollar Amount for your operation.

Coverage Amount: A guaranteed dollar amount of coverage that you select prior to planting. Equals the reference maximum dollar amount times the level of coverage selected.

Stage Guarantee: If a covered crop loss occurs during the first stage of growth (from planting through beginning of tasseling), the indemnity is reduced to 65% of the guarantee.

■ Coverage Levels & Premium Subsidies

Instead of guaranteeing production, this policy guarantees a dollar amount of coverage, depending on the level of

332 Risk Management

coverage selected. Crop insurance premiums are subsidized as shown. For example, if you select the 75% coverage level, the premium subsidy is 55% and your premium share is 45% of the base premium:

Item	Percent						
	CAT	50	55	60	65	70	75
Coverage LEVEL							
Premium Subsidy	100	67	64	64	59	59	55
Your Premium Share	0*	33	36	36	41	41	45

*Catastrophic Risk Protection (CAT) is 100% subsidized with no premium cost to you. CAT insureds pay an administrative fee of \$655 (beginning with the 2020 crop year), regardless of the acreage.

Loss Example

A loss occurs when the crop value falls below the guaranteed dollar amount as a result of damage from a covered cause of loss.

NOTE: Revenue losses caused by low market prices or low consumer demand are not covered.

The example below is based on a dollar guarantee of \$1,723 per acre. This example assumes 50 containers per acre were produced and sold for \$12 per container, less allowable cost of \$4.15, yields a net value of \$7.85 per container.

\$1,723 Dollar amount of coverage selected per acre
 - 393 Production value per acre (50 containers @ \$7.85)
 = \$1,330 Loss per acre

The net indemnity payment will be the loss per acre times the acres covered minus the grower's premium payment for insurance coverage.

Potatoes

Available in specific counties in Connecticut, Maine, Massachusetts, Rhode Island.

Potatoes planted with certified seed for harvest as either certified seed stock or for human consumption may be insured. The policy does not cover any acreage where potatoes are 1) inter-planted with another crop or 2) planted into an established grass or legume.

Causes of Loss

This policy protects against crop loss due to drought, excess rain, excess wind, freeze, hail, failure of irrigation water supply, fire, and wildlife.

NOTE: This policy does not cover any loss of production due to disease or insect infestation, unless effective control measures do not exist for such infestation. For added premium cost, additional endorsements related to storage and quality coverage are available.

Insurance Period

Coverage begins when potatoes are planted. Coverage ends the earliest of (1) total destruction of the crop, (2) harvest of the crop, (3) abandonment of the crop, (4) final adjustment of a claim, or (5) end of insurance date (check with your crop insurance agent for the date in your county).

Reporting Requirements

You must provide an acreage report to your crop insurance agent of all the acres of potatoes in the county in which you have an ownership share by July 15. If damage occurs, you

must notify your crop insurance agent within 72 hours of your initial discovery of damage.

Definitions

Certified Seed: Potatoes entered into the potato certified seed program and meet all requirements for production to be used to produce a seed crop for the next crop year or potato crop for harvest for commercial uses in the next crop year.

Approved Actual Production History (APH) Yield: A yield based on your actual yields, county average yields, or a combination of both. APH is used to determine your production guarantee.

Production Guarantee: Hundredweight (CWT) guaranteed per acre determined by multiplying your approved APH yield by the coverage level percentage you select.

Tuber Rot: Any soft, mushy, or leaky condition of potato tissue including, but not limited to, breakdown caused by Southern Bacterial Wilt, Ring Rot, or Late Blight.

Coverage Levels & Premium Subsidies

Coverage levels range from 50 to 85% of your average yield. Crop insurance premiums are subsidized as shown below. For example, if you select the 75% coverage level, the premium subsidy is 55% and your premium share is 45% of the base premium.

Item	Percent								
	CAT	50	55	60	65	70	75	80	85
Coverage LEVEL									
Premium Subsidy	100	67	64	64	59	59	55	48	38
Your Premium Share	0*	33	36	36	41	41	45	52	62

*Catastrophic Risk Protection (CAT) is fixed at 50% of your average yield and 55% of the price election. CAT is 100% subsidized with no premium cost to you except for an administrative fee of \$655, regardless of the acreage.

Loss Example

A loss occurs when your actual production per acre falls below the guaranteed production per acre.

The example below assumes an average yield of 260 CWT per acre, 65% coverage level, no options or endorsements and one basic unit.

260 CWT per acre average yield (APH)
 x 0.65 Coverage level percentage
 (expressed as a decimal)
 = 169 CWT per acre guarantee

169 CWT per acre guarantee—89 CWT (actual production/acre) = 80 CWT per acre loss (which is then multiplied by # of insured acres and price election to determine Indemnity payment after subtracting the premium).

Download More Information from the Web at:

www.rma.usda.gov

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To file a complaint of discrimination, complete, sign and mail a program discrimination complaint form, (available at any USDA office location or online at www.ascr.usda.gov [4] [4]), to: United States Department of Agriculture; Office of the Assistant Secretary for Civil Rights; 1400 Independence Ave., SW; Washington, DC 20250-9410. Or call toll free at (866) 632-9992 (voice) to obtain additional information, the appropriate office or to request documents. Individuals who are deaf, hard of hearing, or have speech disabilities may contact USDA through the Federal Relay service at (800) 877-8339 or (800) 845-6136.

NON-INSURED CROP DISASTER ASSISTANCE PROGRAM (NAP)

USDA's Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) provides financial assistance to producers of non-insurable crops when low yields, loss of inventory or prevented planting occur due to a natural disaster.

Eligible Producers: An eligible producer is a landowner, tenant or sharecropper who shares in the risk of producing an eligible crop and is entitled to an ownership share of that crop. An individual's or entity's average adjusted gross income (AGI) cannot exceed \$900,000 to be eligible for NAP payments.

Eligible Crops: Eligible crops must be commercially produced agricultural commodities for which crop insurance is not available. Crop insurance agents can answer questions about insurability of crops in specific counties. FSA county offices can provide information on whether a given crop is eligible for NAP coverage.

Eligible Causes of Loss include the following natural disasters:

- Damaging weather, such as drought, freeze, hail, excessive moisture, excessive wind or hurricanes;
- Adverse natural occurrences, such as earthquake or flood; and
- Conditions related to damaging weather or an adverse natural occurrence, such as excessive heat, plant disease, volcanic smog or insect infestation.

The natural disaster must occur during the coverage period, before or during harvest, and must directly affect the eligible crop.

Coverage Level: NAP provides catastrophic level (CAT) coverage based on the amount of loss that exceeds 50 percent of expected production at 55 percent of the average market price for the crop.

Producers have the option of purchasing additional coverage levels ranging from 50% to 65% of production, in 5% increments, at 100% of the average market price. Additional coverage must be elected by a producer by the application closing date. Producers who elect additional coverage must pay a premium in addition to the service fee. Crops intended for grazing are not eligible for additional coverage.

Applying for Coverage: Producers must apply for NAP coverage and pay the applicable service fee at the FSA office where their farm records are maintained. Application closing dates vary by crop.

Sales Closing Dates: The sales closing dates for eligible crops are established by each FSA State Committee. Generally, the closing date is in mid-March for most annual crops in New England and mid- to late-November for perennial crops. Honey, maple, nursery and floriculture crops have different closing dates. It's important to check with the FSA office in your state for the exact dates.

Administrative Fees and Premiums: For all coverage levels, the 2018 Farm Bill increased the NAP administrative fee to \$325 per crop, with a limit of \$825 per producer per county, not to exceed \$1,950 per producer nationwide.

Producers who elect additional coverage must also pay a premium equal to the producer's share of the crop times the number of eligible acres devoted to the crop times the approved yield per acre times the coverage level times the average market price times a 5.25 percent premium fee.

The NAP administrative fee does not apply if you meet the definition of a beginning farmer, limited resource farmer, socially disadvantaged farmer, or veteran farmer. Individuals listed above are also eligible for a 50% reduction to the cost of additional coverage under NAP. Contact your local FSA Office to see if you qualify along with the required reporting requirements.

More Information: More information on NAP is available from your local FSA office. Alternatively, you can go to FSA's website at <https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/noninsured-crop-disaster-assistance/index> which features an online tool to help you determine crop eligibility and premium costs.

WHOLE-FARM REVENUE PROTECTION

Whole-Farm Revenue Protection (WFRP) provides a "safety-net" for all commodities on the farm under one insurance policy.

WFRP replaced and improved upon the two previous whole farm revenue insurance products AGR (Adjusted Gross Revenue) and AGR-Lite (Adjusted Gross Revenue-Lite). By protecting agricultural income rather than crop yields, WFRP extends insurance options to farmers with diverse production and specialty crops, and to farmers relying on local and direct markets, much like AGR. However, the subsidies available for WFRP (up to 80%) are significantly higher than those under the prior AGR program.

Basics

WFRP provides protection against loss of insured farm revenue due to unavoidable natural causes. Insured farm revenue is the farm's approved revenue times the coverage level selected. Coverage levels range from 50% to 85%, increasing in 5% increments.

Approved revenue is based on the lower of:

- The farm's historic average revenue which is derived from 5 consecutive years of a producer's IRS tax forms; or
- The expected revenue for this insurance year

Revenue from all commodities on the farm are covered, except timber, forest and forest products, and animals for sport, show, or pets. Also, revenue from livestock, nursery and greenhouse plants cannot exceed 35% of the farm's expected revenue (with coverage limited to \$2 million for each).

Losses occur when the allowable revenue from the production of commodities produced during the insurance year falls below the insured farm revenue. Notice of losses must be submitted to your crop insurance agent within 72 hours after discovery that farm revenue could be below insured revenue. Claims are made after farm taxes are filed for the insurance year, but no later than 60 days after tax forms have been submitted to the IRS.

WFRP can be purchased alone or in conjunction with other Federal crop insurance policies. When purchased together, the WFRP premium is reduced because of coverage provided by the other policy.

Eligibility

Some of the key WFRP eligibility requirements are that you:

- Be eligible to receive Federal benefits;
- Be a US citizen or resident;
- File a Schedule F tax form (or acceptable substitute);
- Have 5 consecutive years of farm tax history;
- Have no more than \$8.5 million in insured revenue;
- Have no more than 50% of total revenue from commodities purchased for resale; and
- Meet the diversification requirement of having two or more commodities if there are potatoes grown on the farm.

Application

The WFRP sales closing date for the New England states is March 15. To obtain coverage good records are needed. In addition to an application form, producers will need:

- A whole-farm history report showing historical revenues and expenses with supporting information; and
- A farm operations report showing intended production plans for the farm during the insurance year.

A revised farm operations report is due on July 15, noting any significant changes for the farm.

More Information on the Whole-Farm Revenue Protection program:<http://www.rma.usda.gov/Policy-and-Procedure/Insurance-Plans/Whole-Farm-Revenue-Protection>

or contact:

Raleigh Regional Office
4405 Bland Road, Suite 160
Raleigh, NC 27609
Phone: (919) 875-4880

If you want to talk with a crop insurance agent about WFRP, a list of agents in your area may be obtained at: <https://www.rma.usda.gov/en/information-Tools/Agent-Locator-Page>

Written by Michael Sciabarrasi, Extension Professor (Retired), Agricultural Business Management, UNH Cooperative Extension. Updated by Paul Russell & Thomas Smiarowski, Agricultural Risk Management Educators, UMass Extension.

References and Resources

The resources on this list are useful additions to any commercial vegetable grower's library. Many are online and free of charge; otherwise, contact the publisher for pricing information.

Business and Marketing

Sharing the Harvest: Guide to CSA's. E. Henderson and R. Van En. White River Junction, VT, Chelsea Green Publishing, 2007. Order by Phone: 800-639-4099. Order Online: www.chelseagreen.com

The New Farmers' Market. V. Corum, M. Rosenzweig, and E. Gibson. Waldorf, MD, SARE Outreach Publications, 2015. Order by Phone: (301) 374-9696. Order Online: www.sare.org/Learning-Center/Books

The Organic Farmer's Business Handbook. R. Wiswall. White River Junction, VT, Chelsea Green Publishing, 2009. Order by Phone: 800-639-4099. Order Online: www.chelseagreen.com

Crops

Northeast Pepper IPM Manual. J. Boucher. Storrs, CT, University of Connecticut, Communications Resource Center, 2001. Order by Phone: 860-486-3336. Order Online: <http://www.store.uconn.edu/>

Pumpkin Production Guide. Ithaca, NY, PALS (formerly NRAES). Order by Phone: 607-255-7654. Order Online: <http://palspublishing.cals.cornell.edu/>

Sweet Corn Insect Management Field Scouting Guide. R. Hazzard. Northeast IPM Center/UMass Extension, 2012. Free Online: <https://ag.umass.edu/vegetable/publications/guides/sweet-corn-ipm-scouting-guide-record-keeping-book>

Greenhouse and High Tunnels

Greenhouse and Hoophouse Growers Handbook. A. Mefford. White River Junction, VT, Chelsea Green Publishing, 2017. Phone: 800-639-4099. Order Online: www.chelseagreen.com

Greenhouse Engineering, NRAES-33. R.A. Aldrich, and J.W. Bartok. Ithaca, NY, PALS (formerly NRAES), 1994. Order by Phone: 607-255-7654. Free Online: http://host31.spidergraphics.com/nra/doc/Fair%20Use%20Web%20PDFs/NRAES-33_Web.pdf

Greenhouse IPM with an Emphasis on Biocontrols. C. Thomas (Primary Author). University Park, PA. Penn State University, Publications Distribution Center, 2005. Order by Phone: 814-865-6713. Order Online: <https://extension.psu.edu/greenhouse-ipm-with-an-emphasis-on-biocontrols>

New England Greenhouse Floriculture Guide: A Management Guide for Insects, Diseases, Weeds and Growth Regulators, 2019-2020 Ed. Cooperative Extension Service in New England. Order Online: www.negreenhouse.org/index.html

Organic Production

Crop Rotation on Organic Farms. C.L. Mohler and S.E. Johnson. Waldorf, MD, SARE Outreach Publications, 2009. Order by Phone: (301) 374-9696. Free Online: www.sare.org/Learning-Center/Books

eOrganic, a site of eExtension, a part of cooperative extension service. Retrieved July 10, 2019. https://articles.extension.org/organic_production

Organic Production Guides: Cole Crops, Cucumbers and Squash, Lettuce, Peas, Potatoes, Snap Beans, and Spinach, etc. A. Seaman. Ithaca, NY, NY State IPM Program, 2016. Free Online: https://ecommons.cornell.edu/handle/1813/41246/discover?filtertype_1=title&filter_relational_operator_1=contains&filter_1=&query=organic+production&rpp=10

The New Organic Grower. E. Coleman, White River Junction, VT, Chelsea Green Publishing, 2018. Phone: 800-639-4099. Order Online: www.chelseagreen.com

Resource Guide for Organic Insect and Disease Management. B. Caldwell et al. eds. Geneva, NY, New York State Ag. Expt. Station, 2013. Phone: 315-787-2248. Free Online: <http://web.pppmb.cals.cornell.edu/resourceguide/>

Pest Management

Diseases and Pests Compendium Series: (Each crop is a separate publication) Bedding Plants, Bean, Beet, Brassica, Corn, Cucurbit, Lettuce, Onion and Garlic, Pepper, Peas, Potato, Strawberry, Sweet Potato, Tomato, Umbelliferous, etc. D.

Eastburn, (Editor in Chief). St. Paul, MN, APS Press. Order by Phone: 800-328-7560. Order online: <https://my.apsnet.org/APSSStore/>

Diseases and Pests of Vegetable Crops in Canada. R.J. Howard, J.A. Garland, and W.L. Seaman (Eds). Ottawa, Ontario, Canada. Entomological Society of Canada, 1994. Free Online: <https://phytopath.ca/publications/diseases-of-vegetable-crops-in-canada/>

Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production. Cornell Cooperative Extension (Eds). Ithaca, NY. Cornell Cooperative Extension, 2019. Phone: 607-255-7282. Order Online: <https://www.cornellstore.com/2019-Integrated-Crop-and-Pest-Management-Guidelines-for-Commercial-Vegetable-Production?size=83>

Weeds of the Northeast. R.H. Uva, J.C. Neal, and J.M. Ditomaso. Ithaca, NY, Cornell University Press, 1997. Phone: 607-277-2338. Order Online: www.cornellpress.cornell.edu

Post-Harvest

Commercial Storage of Fruits, Vegetables and Florist and Nursery Stocks. K. Cross, Y.W. Chien, and M. Saltveit, (Eds). Agricultural Research Service, Agriculture Handbook 66, 2016. Order print copy: Catherine Parsons, USDA-ARS Food Quality Laboratory, 10300 Baltimore Ave., Bldg.002, Beltsville, MD 20705. Free Online: <https://www.ars.usda.gov/is/np/CommercialStorage/CommercialStorage.pdf>

Soil Management

Building Soils for Better Crops, 3rd Edition. H. Van Es, and F. Magdoff. College Park, MD. SARE Outreach Publications, 2010. Order by phone: (301) 779-1007. Free Online: www.sare.org/Learning-Center/Books

Managing Cover Crops Profitability, 3rd Ed. A Clark, (Ed). Waldorf, MD, SARE Outreach Publications, 2013. Order by Phone: (301) 374-9696. Free Online www.sare.org/Learning-Center/Books

On Farm Composting Handbook. R. Rynk (Ed). Ithaca, NY. PALS (formerly NRAES), 1992. Order by Phone: 607-255-7654. Free Online: <https://campus.extension.org/pluginfile.php/48384/course/section/7167/NRAES%20FarmCompost%20manual%201992.pdf>

Other/General

Knott's Handbook for Vegetable Growers, 5th Ed. D.N. Maynard, and G.J. Hochmuth. Indianapolis, IN, John Wiley and Sons, 2007. Order by Phone: 877-762-2974. Order Online: www.wiley.com

Production of Vegetables, Strawberries and Cut Flowers Using Plasticulture. W.J. Lamont. Ithaca, NY, PALS (formerly NRAES). Order by Phone: 607-255-7654. Order Online: <http://palspublishing.cals.cornell.edu/>

Steel in the Field: Guide to Weed Management Tools. G. Bowman (Ed). Beltsville, MD, SARE Outreach Publications, 2002. Order by Phone: 301-374-9696. Free Online: www.sare.org/Learning-Center/Books

Sustainable Vegetable Production from Start-up to Market. V. Grubinger. Ithaca, NY, PALS (formerly NRAES), 1999. Order by Phone: 607-255-7654. Order Online: <http://palspublishing.cals.cornell.edu/>

Vegetables: Characteristics, Production and Marketing. L.C. Pierce. Indianapolis, IN, John Wiley and Sons, 1987. Order by Phone: 877-762-2974. Order Online: www.wiley.com

Video Series for Vegetable Farmers: Farmers and their Diversified Horticultural Marketing Strategies, Farmers and their Ecological Sweet Corn Production Practices, High Tunnels: Low Cost Season Extension, Vegetable Farmers and their Innovative Cover Cropping Techniques, Vegetable Farmers and their Sustainable Tillage Practices, Vegetable Farmers and their Weed Control Machines.[DVDs] V. Grubinger, V. and M.J. Else, (Producers) Burlington, VT, University of Vermont Center for Sustainable Agriculture and Northeast Sustainable Agriculture Research and Education Program. Free Online: <https://articles.extension.org/pages/18726/video-clips-about-organic-farming-by-eorganic>

Conversion & Dilution for Fertilizers & Pesticides

TABLE OF EQUIVALENTS FOR MEASURING LIQUIDS

3 teaspoons or 1/2 fluid ounce = 1 tablespoon
2 tablespoons = 1 fluid ounce
16 tablespoons = 8 fluid ounces = 1 cup = 1/2 pint
16 fluid ounces = 2 cups = 1 pint
1 pt of formulation/100 gal = 1 teaspoon/gal

PRACTICAL DILUTION CHART FOR PREPARING LESS THAN 100 GALLONS OF PESTICIDE SPRAY

	Gallons of Finished Spray*		
	100 gal	25 gal	1 gal
Amount of EC or other liquid formulation to be used	1/2 pt (1 cup)	2 fl oz (4 Tbsp)	1/2 tsp
	1 pt	4 fl oz (8 Tbsp)	1 tsp
	1 qt	1/2 pt (1 cup)	2 Tsp
	1 gal	1 qt	2-1/2 Tbsp
Amount of WP or other powder formulation to be used	1 lb	1/4 lb (4 oz)	1/6 oz (5 g)
	2 lb	1/2 lb	1/3 oz (10 g)
	3 lb	3/4 lb	1/2 oz (14 g)
	4 lb	1 lb	2/3 oz (20 g)

*NOTE: The number of pints/100 is the same as the number of fluid ounces required in 6-1/4 gals.

AMOUNTS OF A COMMERCIAL PRODUCT (FORMULATION) NEEDED TO PROVIDE VARIOUS AMOUNTS OF ACTUAL PESTICIDE PER 100 GALLONS OR PER ACRE

Commercial Products (lbs of pesticide per gal of formulated material)	Pounds of actual pesticide per 100 gallons			
	1/2 lb	1 lb	3 lb	5 lb
1.5 EC (1-1/2 lb per gal)	1-1/3 qt	2-2/3 qt	2 gal	3-1/3 gal
2 EC (2 lb per gal)	1 qt	2 qt	1-1/2 gal	2-1/2 gal
4 EC (4 lb per gal)	1 pt	1 qt	3 qt	5 qt
6 EC (6 lb per gal)	2/3 pt	1-1/3 pt	1-1/2 qt	2-1/2 qt
8 EC (8 lb per gal)	1/2 pt	1 pt	1-1/2 qt	2-1/2 qt
15 WP	3-1/3 lb	6-2/3 lb	20 lb	33 1/3 lb
25 WP	2 lb	4 lb	12 lb	20 lb
40 WP	1-1/4 lb	2-1/2 lb	7-1/2 lb	12-1/2 lb
1% dust/granules	50 lb	100 lb	300 lb	500 lb
1-1/2% dust/granules	33 lb	67 lb	200 lb	333 lb
2-1/2% dust/granules	20 lb	40 lb	120 lb	200 lb
5% dust/granules	10 lb	20 lb	60 lb	100 lb

EC = emulsifiable concentrate (liquid) WP = wettable powder

USE OF TABLESPOONS (DRY MATERIALS ONLY)

The number of tablespoons per ounce, or cups per pound, of dry insecticides and fungicides varies greatly with different products because some materials are light and fluffy; others compact and heavy. In general, there are from 2 to 6 level tablespoons per ounce of these dry materials.

When a material is to be used repeatedly, it is much better to weigh out the amount needed and place it in some convenient container which can be easily marked. If this cannot be done, it is usually safe to assume that 1 lb per 100 gal is equal to 1 level Tbsp/gal. (For example, Sevin - 2 lb/100 gal = 2 Tbsp/gal.)

AREA CONVERSION

Amount / A ÷ 44 (or 43.5) = amount needed per 1,000 sq ft.

In case of suspected pesticide poisoning get prompt medical attention!

POISON INFORMATION CENTER TELEPHONE NUMBER

The previous numbers for state poison control centers have been replaced by a national toll-free Poison Information number. The equipment automatically detect the area code you are calling from, and connects to your state's center.

Some Poison Information Center numbers will eventually be terminated. In the event of a PESTICIDE POISONING, please use the new number:

1-800-222-1222

YOUR LOCAL AMBULANCE _____

YOUR LOCAL HOSPITAL _____

YOUR DOCTOR _____

YOUR LOCAL FIRE DEPARTMENT _____

State contact # to report pesticide spill _____



Vegetable

Management Guide 2020-2021
New England Region

Useful Vegetable Extension Websites in New England

University of Connecticut	http://ipm.uconn.edu
University of Maine	http://extension.umaine.edu/agriculture/
University of Massachusetts	http://ag.umass.edu/vegetable/
University of New Hampshire	http://extension.unh.edu/programs/fruit-vegetable-crops
University of Rhode Island	https://web.uri.edu/coopext/food-systems/
University of Vermont	http://www.uvm.edu/vtvegandberry/

The *New England Vegetable Management Guide*
is available online at www.nevegetable.org